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«Sciences of Europe» -
Editorial office: Křižíkova 384/101 Karlín, 186 00 Praha

E-mail: info@european-science.org
Web: www.european-science.org

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# AGRICULTURAL SCIENCES

## THE STATE OF IRRIGATED SOILS IN THE KURA-ARAKS LOWLAND OF AZERBAIJAN

***Ramazanova F.***
*leading researcher of laboratory of soil genesis and geography, candidate of agricultural sciences (PhD), Associate Professor of Soil Science, Plant Growing, Ministry of Science and Education of Azerbaijan Institute of Geography Public Legal*
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**ABSTRACT**
Irrigated soils in the Kura-Araks Lowland are subject to irrigation-induced erosion, natural water and wind erosion, and salinization. Of the 2,098,800 hectares of agricultural land in the lowland, the areas of land subject to erosion and salinization reach 333,600 and 373,398 hectares, respectively. The relationship between irrigation-induced erosion and soil type (gray sierozems, meadow sierozems, and graeycinnamonic soils), irrigation furrow slope, irrigation water salinity (0.15–0.95 g/L), and water flow (0.8–1.4 L/s) was studied. It was found that soil erosion and salinization lead to changes in soil density and porosity, as well as a decrease in humus and nutrient content. Certain changes in soil texture also occur. The area of land susceptible to erosion from heavy, moderate, and light rainfall is estimated at 57,700, 24,400, and 15,300 hectares, respectively. Measures to combat soil erosion and salinization are discussed. Main types of soil degradation in the Kura-Araks lowland of Azerbaijan.
**Keywords:** irrigationinduced erosion, wind erosion, salinization, slope of the surface, degree of erosion, sierozems, meadowsierozemic soils, light graycinnamonic soils.

### 1. INTRODUCTION

Land degradation is an urgent problem for Azerbaijan, as well as for other arid. Land degradation results in lower soil fertility and, thus, in declining living regions [2, 5, 8, 12] standards of people. This process is especially intensive in the Kura–Araks Lowland. The main types of degradation are irrigationinduced erosion, natural water and wind erosion, and salinization [17]. The Kura–Araks Lowland is the cotton, grain, legume, and fruit base of Azerbaijan. The study of the factors and regularities of the anthropogenic soil degradation is necessary for adequate use and protec tion of soil resources in this area [7, 17].

### 2. OBJECTS AND METHODS

The area of agricultural land in the Kura–Araks Lowland is 2098.8 thousand ha. The absolute heights of the lowland vary from 28 to 101 m a.s.l. This territory is a slightly dissected undulating plain composed of alluvial heavy loams, clays, sands, and gravelly sed iments. The surface inclination varies from 0.0001° to 0.100° in the western elevated part of the lowland and from 0.001° to 0.065° within the irrigated area on the lower accumulative plains of the KuraAras Lowland. The studied area is characterized by a subtropical climate with a dry and hot summer. The mean annual temperature is 12–13°C, and the mean January temperature is +3.9–5.2°C, so the soils do not freeze. The sum of active (>10°C) daily temperatures reaches 4000–5200 degreedays, the mean annual precipitation does not exceed 180–450 mm, and the humidity factor varies within 0.3–0.15 [4, 6, 10, 15].

Field studies were performed on key sites in the Mugan'–Sal'yansk, Mil'sk, Karabakh, and Shirvan steppes of the Kura–Araks Lowland. We studied sierozems (Calcisols), meadowsierozemic soils (Gleyic Calcisols), light gray cinnamonic soils (Haplic Kastanozems), and their irrigated analogues, which represent the main soil resources of the area.

**Sierozemic soils** (Calcisols) are allocated to gently sloping plains with mesodepressions at heights from 11 to 200 m a.s.l. (mainly, in the Shirvan and Mugan'–Sal'yansk steppes). They are developed from marine and mud volcanic loamy, clay loamy, and clayey deposits and from the alluvial sediments. The natural plant cover is represented by the grass–wormwood–caragana associations. The sierozems are saline soils: the salt content in the layer of 0–2 m is from 1.5 to

3.0%. The salinization is of the chloride–sulfate type. The humus content in the upper 25 cm varies from 1.61 to 2.15%.

**Meadow sierozemic soils** (Gleyic Calcisols) are allocated to inclined plains, footslopes, and mesode pressions at heights from 11 to 300 m a.s.l.; they are widespread on the Mugan'–Sal'yansk, Mil'sk, Shirvan, and Karabakh steppes. These soils are developed from colluvial and alluvial loesslike loams under wormwood–ephemeral plant communities. The soils are often calcareous and contain soluble salts (0.34–1.06%) in the upper 2 m. The salinization is of the chloride–sulfate type. The humus content in the upper cm is 2.00–2.10%.

**Light graycinnamonic soils** (the type of mountain ous gray cinnamonic soils) are developed from the Upper Quaternary clays and heavy clays of alluvial origin at heights from 70 to 300 m a.s.l. under conditions similar to those of the chestnut soils. They are allocated to dry steppes and semideserts on the foothills of the Minor and Great Caucasian ranges. The plant cover is composed of the grassy–wormwood-ephemeral vegetation. The soils are often calcareous and slightly saline (0.11–0.60%). The salinization is of the chloride–sulfate type. The humus content in the upper 25 cm is 2.15–2.48%.

The upper boundary of carbonate accumulation in the irrigated sierozems, meadow sierozemic, and light gray cinnamonic soils is deeper as compared to the rainfed soils. The meadow sierozemic and light gray cinnamonic soils are also characterized by the presence of gypsum in the deep layers. Irrigationinduced erosion and natural water erosion were studied in the field.

Running irrigation water was sampled from irrigation furrows 5, 15, 60, 120, 180, and 240 min after the beginning of irrigation and in the last hours of irrigation in three replicates according to the method suggested by M.S. Kuznetsov. Morphometric measurements of the appearing rills were also performed [11].

The irrigation water flows were measured at the beginning and end of the furrows using Thomson'sgauges (45°); the flow velocity in the furrows was determined with the use of a coloring liquid and timer and regulated with polyethylene blankets. The wind erosion was studied according to Zaslavskii [16]. Archive data of the Institute of Soil Science and Agricultural Chemistry of the National Academy of Sciences of Azerbaijan were used to judge the degree of soil salinization [3]. The areas of degraded soils were calculated according to a digitized map of soil degradation in the Kura–Araks Lowland developed by E.A. Kurbanov (Institute of Soil Science and Agricultural Chemistry of the National Academy of Sciences of Azerbaijan) with the use of Access–(ArcGIS) software [9].

## 3. RESULTS AND DISCUSSION

The Kura-Araks Lowland is subdivided into five phys iographic regions (steppes): the Mugan'–Sal'yansk, Mil'sk, Karabakh, Shirvan, and Gyandzha steppes. The Shirvan Steppe is found on the left bank of the Kura River; the Gyandzha, Karabakh, and Mil'sk steppes occupy the Kura–Araks Interfluve; the Mugansk Steppe is found to the south of the Aras River; and the Sal'yansk Steppe occupies the right bank of the Kura River in its lower reaches. Each of the steppes is characterized by a specific climate, topography, soils, and vegetation.

Irrigationinduced and wind erosion are wide spread in the KuraAraks

Lowland. Irrigationinduced erosion is typical of the entire semidesert zone and piedmonts with an inclination of more than 0.003. Wind erosion is developed along the Kura River (on the southeastern parts of the Shirvan and Sal'yansk steppes) and in the western part of the lowland. The arid climate, coarse soil texture, strong local winds, and extreme grazing loads favor the development of wind erosion (Table 1). The degree of erosion was evaluated on the basis of the following diagnostic criteria: the decrease in the thickness of the humus horizon and humus content in the soil profile, the decrease in the pool of soil nutrients, the changes in the topsoil texture and flow rates,the inclination of the surface, the intensity of the wind erosion, the thinning of the grass cover and crops, the total salt content in the top fertile layer, the soil reaction (pH of the water extract), etc.

Table 1.

Area of eroded lands in the Kura–Aras Lowland (2009, thousand ha)

| Region | Total area | Total area of eroded lands | Areas with different types of erosion | | | | |
|---|---|---|---|---|---|---|---|
| | | | rainstorm | | | Irrigation-induced | wind |
| | | | degree of erosion | | | | |
| | | | weak | mediums | strong | | |
| Mugan'-Sal'yansk massif | 871.1 | 131.2 | 21.7 | 11.7 – | - | 36.2 | 61.6 |
| Shirvan Steppe | 508.0 | 116.9 | 16.0 | 8.3 | 8.6 | 41.5 | 42.5 |
| Mil'sk Steppe | 477.9 | 29.7 | 1.9 | 0.6 | – | 24.5 | 2.7 |
| Karabakh Steppe | 241.8 | 55.8 | 18.1 | 3.8 | 6.7 | 24.9 | 2.3 |
| Total | 2098.8 | 333.6 | 57.7 | 24.4 | 15.3 | 127.1 | 109.1 |

Water erosion. More than 64% of the irrigated lands in the lowland are allocated to inclined surfaces. Three types of irrigationinduced erosion can be distinguished:

(1) sheet erosion of the topmost horizons of irrigated soils under the impact of both irrigation waterand rainstorms;

(2) rill erosion, including bottom and side erosion of the irrigation network followed by the formation of deeper hollows and ravines;

(3) destruction of the irrigation network with the removal of topsoil horizons and the formation of mudflows. Rainstorm erosion is especially intensive on winterpastures with slopes of 5°–7° upon overgrazing, when the barren soil surface makes the soil susceptible to erosion. The soil loss tolerance increases with an increase in the contents of clay, humus, and bivalent cations. Rainstorm erosion is especially pronounced on sierozems of the Shirvan steppe (8.6 thousand ha). These soils are developed under thin vegetation cover and are characterized by a low content of the clay (<0.001 mm) fraction (11.0–18.0%) and humus (1.3–1.6%). Soil washout takes place under the impact of heavy rains in the spring and fall seasons. In the case of irrigationinduced erosion, three zones of the washout, stabilization, and accumulation of sediments are formed along the furrows in dependence on the local topography and the length of the furrow. The uneven surface of irrigated plots enhances the washout and accumulation of sediments. Soil erosion in furrows is mainly seen in their most inclined parts.

Data on the intensity of the irrigation-induced erosion in dependence on the slope of the surface and the water discharge rates are given in Table 2.

Table 2.

Irrigationinduced erosion as dependent on the slope of the surface and irrigation water discharge

| Slope; soil | Furrow length, m | Water discharge in furrow, L/s | Water turbidity, g/L | Soil washout per one irrigation, t/ha |
|---|---|---|---|---|
| 0.006, heavy loamy light sierozemic | 200 | 0.6<br>0.8<br>1.0<br>1.2 | 8.25<br>13.67<br>16.82<br>21.54 | 2.26<br>4.68<br>6.41<br>8.84 |
| 0.018, heavy loamy light sierozemic | 200 | 0.2<br>0.4<br>0.6<br>0.8 | 9.44<br>15.28<br>20.65<br>26.76 | 2.78<br>6.42<br>10.74<br>14.86 |
| 0.012, medium loamy typical sierozemic | 200 | 0.4<br>0.6<br>0.8<br>1.0 | 13.80<br>19.63<br>23.84<br>26.47 | 2.23<br>3.48<br>5.20<br>7.12 |
| 0.003, medium loamy meadowsi erozemic | 250 | 0.8<br>1.0<br>1.2<br>1.4 | 4.56<br>5.12<br>7.24<br>9.10 | 2.44<br>2.98<br>3.45<br>4.16 |
| 0.020, medium loamy light graycinna monic (chestnut) | 150 | 0.2<br>0.4<br>0.6<br>0.8 | 9.13<br>15.56<br>19.34<br>24.78 | 2.54<br>5.82<br>9.16<br>13.40 |

They show that the soil erosion depends on the slope gradient, water discharge, and soil loss tolerance. Thus, in the case of a furrow gradient of 0.006, water discharge rates of 0.6 and 1.2 L/s, and a furrow length of 200 m, the turbidity of the discharged water on heavy loamy light sierozems reaches 8.25 and 21.54 g/L, which corresponds to the washout of 2.26 and 8.84 t/ha, respectively. At a higher slope gradient (0.018), water discharge rates of 0.2 and 0.8 L/s, and a furrow length of 200 m, the turbidity constitutes 9.44 and 26.76 g/L, which corresponds to the washout of 2.78 and 14.86 t/ha, respectively. The smallest soil washout perone irrigation (2.44–4.16 t/ha) is seen at a slope gradient of 0.003, a furrow length of up to 250 m, and awater discharge rate of 0.8–1.4 L/s.

In the case of furrow erosion, the texture of the surface soil horizon becomes coarser due to the removal of the clay fractions. These fractions tend to accumulate in distant (lower) parts of the furrows.

The worsening of the structural state of eroded soils exerts a negative impact on other soil properties and regimes. Disaggregation and compaction of irrigated soils often lead to the soil overcompaction. This is especially the case for the plow horizons, though some soil compaction takes place also in the deeper layers. The nonuniform soil texture on the fields complicates agricultural works and crop growing. Thin surface crusts are developed in the furrows, whereas the layers of accumulated sediments on the soil surface may have considerable thickness. Upon drying, these irrigation deposits are transformed into cemented surface horizons with high bulk density preventing the development of plants.

Irrigation-induced erosion on the light gray-cinnamonic and meadow -sierozemic soils leads to anincrease in the soil bulk density up to from 1.09–1.46 and 1.20–1.58 g/cm$^3$, respectively; the hydraulic conductivity of these soils decreases to 1.6–1.7 and 1.2–1.5 mm/min, respectively. The bulk density of the soil in the eroded part of the furrows is somewhat lower, because the less compact lower soil horizon becomes exposed to the surface.

The contents of humus, nitrogen, phosphorus, and potassium in the suspended sediments are higher than those in the plow layer. For example, in the light graycinnamonic soil, the humus content in the upper 25 cm is 2.00–2.15%; in the suspended sediments washed out from the soil, it is 0.50–0.84% higher and reaches 2.84% in the case of the water discharge rate of 0.2 L/s (Table 3). The contents of humus, total nitrogen, and phosphorus in the suspended sediments at the ends of the furrows (where the rate of water discharge decreases) are 20–30% higher than those in the suspended sediments at the beginning of the furrows with the higher rates of water discharge.

Table 3.

Humus and nutrient contents in the washed out sediments

| Slope; soil | Water discharge | Humus | Nitrogen | Phosphorus | Potassium |
|---|---|---|---|---|---|
| | | % | | | |
| 0.006, heavy loamy light sierozemic | 0.6 | 3.00 | 0.20 | 0.23 | 2.54 |
| | 0.8 | 2.92 | 0.19 | 0.23 | 2.50 |
| | 1.0 | 2.80 | 0.19 | 0.22 | 2.51 |
| | 1.2 | 2.80 | 1.2 | 2 1.2 | 2.50 |
| 0.018, heavy loamy light sierozemic | 0.2 | 2.11 | 0.16 | 0.19 | 2.49 |
| | 0.4 | 2.05 | 0.16 | 0.18 | 2.52 |
| | 0.6 | 2.05 | 0.15 | 0.18 | 2.50 |
| | 0.8 | 1.98 | 0.15 | 0.17 | 2.51 |
| 0.012, medium loamy typical sierozemic | 0.4 | 3.20 | 0.22 | 0.27 | 2.68 |
| | 0.6 | 3.00 | 0.21 | 0.25 | 2.64 |
| | 0.8 | 3.00 | 0.19 | 0.25 | 2.66 |
| | 1.0 | 2.90 | 0.19 | 0.25 | 2.64 |
| 0.020, medium loamy light graycinnamon ic (chestnut) | 0.2 | 2.84 | 0.16 | 0.18 | 2.67 |
| | 0.4 | 2.72 | 0.14 | 0.17 | 2.69 |
| | 0.6 | 2.53 | 0.13 | 0.17 | 2.65 |
| | 0.8 | 2.50 | 0.13 | 0.16 | 2.68 |

The evaluation of the humus and nutrient losses shows that they are in direct correlation with the water discharge. Thus, upon the surface gradient of 0.020 (irrigated graycinnamonic soils) and a furrow length of 150 m, the losses are 55.88 kg/ha for humus, 4.06 kg/ha for nitrogen, 4.57 kg/ha for phosphorus, and 67.82 kg/ha for potassium at the water discharge rate of 0.2 L/s. They increase up to 247.90, 17.42, 21.44, and 352.42 kg/ha, respectively, at the water discharge rate of 0.8 L/s.

**Deflation.** Pastures and plowlands are subjected to wind erosion at wind velocities of about 5 m/s and higher in any season. The development of wind erosion is especially pronounced in seasons when the soil is loose, dry, and not covered by vegetation. Wind erosion is developed on winter pastures and plowed fields. It is enhanced at excessive grazing loads, improper technologies of soil cultivation, thin vegetation, and the presence of carbonates and salts in the upper soil horizons.

The air humidity and temperature exert an indirect impact on the wind erosion. It begins at the soil moistening of less than 12–15%. In the arid climate, even small changes in the wind velocity under the impact of the local conditions may cause the development of wind erosion up to dust storms. On the southeastern Shirvan and Sal'yansk steppes, local wind erosion may take place even under the impact of weak winds (5–6 m/s). Up to 50% of the substances may be blown out from the upper 15–20 cm of the soil.

The soil texture is an important factor of wind erosion. Coarse-textured (sandy) soils are particularly susceptible to wind erosion. The changes in the physicochemical properties of sierozemic and light gray-cinnamonic soils subjected to wind erosion are the most pronounced. In the eroded soils, the content of the sand fraction in the upper layers (0–15 and 0–50 cm) increases by 10–15%, the content of the silt fractions decreases by 30–50%, and the content of the clay fractions decreases by 15–40% as compared with the noneroded soils. On eolian hills, the amount of the sand fraction rises by up to three times; the silt and clay fractions are blown out from the soil material.

The eroded coarsetextured soils are characterized by a decrease in the humus content by 20–40%, the content of total nitrogen by 8–45%, the content of available phosphorus by 10–30%, and the content of exchangeable potassium by 10–40%. Eolian hill ocks formed near shrubs are characterized by a lower contents of humus (by 40–70%), total nitrogen (by 20–70%), available phosphorus (by 20–60%), and exchangeable potassium (by 5–35%) in comparison with the noneroded soils.

**Salinization.** The development of soil salinization depends on the local topographic features, the irrigation regime, and the groundwater regime. Intense salinization of the root zone is related to degradation of irrigation systems with the development of water infiltration from the beds of unlined irrigation canals, the absence or bad work of drainage systems, and other factors. Huge losses of irrigation water due to infiltration and poor drainage of irrigated lands result in a rise of the groundwater level; in many cases, a rise in the salinity of the irrigation water is also observed. The development of secondary soil salinization is an acute problem of irrigation farming in arid regions. Soil salinization may be also related to natural processes of salt accumulation in the intermontane depressions and on the floodplains and footslopes in the arid zone.

In the past 60 years, certain changes in the environmental conditions of the Kura–Aras Lowland (climate warming, higher potential evaporation, increased activity of bottom erosion in the ravines and river valleys, and frequent floods) have led to the increased inflow of saline groundwater from the deep horizons into the Kura, Akusha, Akhsuchai, and other rivers. Anthropogenic factors (irrigation without drainage with an uncontrolled water supply, excessive moistening, and others) have resulted in the rise of the ground and irrigation water salinity by almost two times and the enhancement of salinization on irrigated lands.

In 2010, the area of saltaffected irrigated soils in the Kura–Araks Lowland reached 373 398 ha. The largest area of saltaffected soils is found on the Mugan'–Sal'yansk Steppe (169 915 ha). Salinization of the vir-

gin land in this region is caused by the arid climate, excessive grazing pressure resulting in deterioration of the plant cover, enhanced physical evaporation from the soil surface, and the rise in the groundwater level.

Salinization of irrigated lands in the Mugan'–Sal'yansk Steppe is related to irrigation with saline water from the Kura and Akusha rivers (0.52–1.46 g/L) and from the Mugansk, Azizbekov, and Sabir canals (0.46–1.98 g/L). These waters transport up to 3600–8760 and 8100–11 880 kg/ha of salts, respectively, to the irrigated fields during the growing season.

The inclined surface of the Mugan'–Sal'yansk Steppe with depressions in places, the Quaternary deposits related to transgressions and regressions of the Caspian Sea, the shallow groundwater (3.0–4.0 m and 2.0–3.0 m in places), the absence of an artificial drainage network, the water infiltration through the bottoms and walls of irrigation canals, and the recent rise in the groundwater level to critical levels favor the active development of soil salinization in this area.

The variations in the salt content in the soils of the Kura–Aras Lowland depend on the concentration of salts in the irrigation water, the degree of drainage of the territory, and the groundwater regime. The ion concentrations in the irrigation water vary within the following values (g/L): 0.224–0.353 for, 0.099–0.171 for Cl–, 0.443–0.908 for, 0.094–0.164 for $Ca2^{+}$,0.046–0.121 for $Mg2^{+}$, and 0.094–0.283 for $Na^{+} + K^{+}$.

Turbid river water and clean artesian water and water from the kyariz (qanat) underground water systems are used for irrigation. The water salinity in the main canals is higher (0.39–1.98 g/L on the average) than in the rivers (0.4–1.1 g/L). This is explained by the fact that the river water is subjected to rapid sea sonal changes in dependence on the particular weather conditions. In periods when the surface water supply (rain, snow, and others) predominates, the salinity of the river water decreases; it increases in periods with ahigher portion of the groundwater supply. In canals, the water is slowly renewed and is mainly supplied from storage reservoirs. The water salinity in such reservoirs increases because of evaporation from the open surface, the discharge of wastewater, and some other factors, which greatly affects the quality of the irrigation water.

The water salinity is the highest in the Akhsuchai, Akusha, and Kura Rivers (0.6–1.46 g/L) and in the Azizbekov, Mil'sk, and Mugansk canals (0.59–1.98 g/L). The lowest water salinity is typical of the Bolgarchai, Khachinchai, Kuruchai, and Kargarchai Rivers (0.26–0.4 g/L). In some years, the water salinity in the Aras River system may rise up to 1.5 g/L. About 50–60 years ago, the water salinity in the Kura and Aras rivers was 0.4–0.6 and 0.6–0.8 g/L, respectively. It has increased by two–three times since that time [1].

The irrigation water brings 1680–11 880 kg/ha of soluble salts to the fields per growing period, which favors an increase in the area of saltaffected soils with a corresponding decrease in the yields of cotton and other crops. Taking into account the specific features of the soils in the Kura–Araks Lowland, high duties of irrigation water are not permissible there. The following measures can be recommended to control the development of soil erosion and salinization in this area:

(1) Phytomelioration of irrigated lands with the use of zonal agrotechnologies including surface planning of irrigated land, the creation of dense plant cover providing for the biological loosening of the soil by the roots and considerable supply of the soil with fresh organic matter (stubble and root remains), sowing of halophytes (Agropyron elongatum and Kochia prostrata) in the areas with saline soils, planting of trees along ditches and canals to lower the groundwater level, etc.

(2) Proper construction and maintenance of irrigation systems with due respect for the quality of the soils, their textures, and the groundwater level and salinity; irrigation canals should have waterproof beds; vertical and deep (2.5–3.5 m) horizontal drainage systems should be constructed; a more progressive method of sprinkling irrigation should be applied; and deep wells and a drainage network should be constructed in order to lower the groundwater level.

(3) The grazing pressure on pastures should be optimized; grass sowing, planting of shelterbelts, and protection of the biological diversity in natural pasture ecosystems should be organized. The processes of water and wind erosion have some features in common; similar measures are often required to control them. In particular, the growing of intermediate crops is an efficient measure to protect the soils from wind and water erosion.

In 2016–2022, mixed sowing of main and intermediate forage crops was performed as a measure to control the water and wind erosion and improve the soil fertility. This phytomeliorative measure was applied on the Shirvan steppe (Kyurdamir and Udzhar, irrigated meadowsierozemic soil) and Gyandzha–Kazakh massif (Akstafa, irrigated graycinnamonic soil). According to the zonal recommendations, minimum tillage was applied. The scheme of crop sowing was as follows: (winter sowing) rye + vetch + rape (for green fodder) / (after harvesting) corn + soya + sorghum +amaranth 1: 1: 1: 1 (for green fodder) / (after harvesting) barley + vetch (for green fodder). Irrigation of all the crops was aimed to maintain the soil moisture in the upper 75 cm at the level of no less than 70–75% of the field capacity. Furrow irrigation was applied.

The plant cover formed by these crops on the irrigated meadowsierozemic and graycinnamonic soils was dense and favored greater accumulation of the root mass and the soil enrichment with fresh organic matter all year round (8.9–10.2 and 11.0–12.3 t/ha of airdry mass of stubble and root remains with a high content of ash elements (1.80–5.91%), nitrogen (0.88–1.79%), phosphorus (0.48–0.89%), and potassium (0.35–1.97). The yield of the crops (in fodder units) increased by 2.5 times.

In the years with intermediate forage crops sown, the bulk density, porosity, structure, and biological characteristics of the irrigated meadowsierozemic and gray-cinnamonic soils were quickly restored to the normal values. The total content of dissolved solids (TDS) in water extracts from the irrigated meadowsierozemic soil (0–2 m) decreased from 0.34–0.46% at the beginning of the experiment to 0.17–0.27%. The soil bulk density decreased by 10–12% in the upper 70 cm and by 20–30% in the layer of 0–100 cm. In the irrigated gray cinnamonic soil, the TDS dropped to 0.05–0.09%,

and the soil bulk density decreased by 12–15 and 25–35%, respectively. The soil washout decreased by 3–7 times.

The agrochemical characteristics of the plow layer (0–27 cm) improved in both soils. A reliable ten dency for a rise in the content of humus and nitrogen by 0.38–0.40% as compared with the initial level was observed. The pool of humus increased from 67.4 to 75.5 t/ha, while the pool of nitrogen, from 5.70 to 5.94 t/ha. The available phosphorus content increased from 17–19 mg/100 g to 22–28 mg/100 g in the plow layer (0–27 cm), but it somewhat decreased in the lower (27–55 cm) layer. The content of exchangeable potassium increased from a low level to a medium level in both layers.

Base saturation plays an important role in soil fertility. The higher the base saturation, the better the physicochemical soil properties. $Ca^{2+}$ and $Mg^{2+}$ cations are good coagulators and improve the soil structure. In the plow layer of the irrigated gray-cinnamonic soil, the base saturation in aggregates <10 mm reached 67–75% (higher than moderate). In the irrigated meadow-sierozemic soil, it was somewhat lower (60–66%).

The comparison of the data on the chemical composition of the water extracts from the soils of the experimental plots obtained in 2012 and 2004 shows that the salt content in the 1mdeep layer decreased to 0.145–0.165% in the irrigated meadow-sierozemic soil and to 0.07–0.12% in the irrigated gray-cinnamonic soil.

The content of agronomically valuable soil aggregates (0.25–10 mm) increased by 8.8–14.9% in the irrigated gray-cinnamonic soil and by 6.8–12.1% in the irrigated meadow-sierozemic soil. The rise in the content of water-stable aggregates was due to the structuring role of the root systems of rye, vetch, soya, rape, corn, sorghum, and amaranth; the soil enrichment with organic matter; and the high content of calcium in the remains of these plants.

Biological soil properties are important indicators of soil fertility [14]. Stubble and root remains (8.9–10.2 and 11.0–12.3 t/ha of airdry mass of three crops in a year) admixed into the plow layer (0–27 cm) enhanced the biological activity of the soils. The total number of microorganisms increased by 1.3–1.9 times, the portion of bacteria increased by 68–74%, and the portions of actinomycetes and fungi decreased by 24.5–27.4 and 0.04–0.08%, respectively. Thus, intermediate leguminous–grass–cruciferous forage crops had a strong phytomeliorative effect.

## CONCLUSIONS

(1) The geomorphologic and climatic conditions and improper management of natural pastures and irrigated lands in the Kura–Aras Lowland favor intensive development of irrigationinduced and natural water erosion, wind erosion, and salinization.

(2) Irrigationinduced erosion results in the washout of 2.23–14.86 t of soil, 56–304 kg of humus, 4–21 kg of nitrogen, and 4.6–26.6 kg of phosphorus and other nutrients per hectare during one irrigation in dependence on the slope of the furrows (0.003–0.020) and water discharge rates (1.4–0.8 L/s).

(3) Wind erosion of sierozemic and gray-cinnamonic soils results in an increase in the content of the sand fraction by 10–15% with a drop in the contents of the silt and clay fractions by 30–50 and 1–40%, respectively; the humus content in the eroded soils decreases by 20–40%.

(4) The higher salinity of the irrigation water (up to 1.5–1.98 g/L) enhances the soil salinization. The total area of salt-affected soils has reached 373 398 ha, which is two times higher than that in 1950–1960.

(5) The optimum combination of main and intermediate forage crops with their proper distribution in space and time is an efficient measure to control water and wind erosion. It lowers soil erosion by three–seven times; ensures the significant accumulation of organic matter in the plow layer (0–27 cm); increases the biological activity of the soil by 35–40%; the pools of humus, nitrogen, and available phosphorus in the soil increase; and the soil salinity and bulk density decrease.

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# ART STUDIES

## ПРОЦЕСС ПЕРЕДАЧИ ЭМОЦИЙ И ХАРАКТЕРА ЧЕРЕЗ ГРАДАЦИИ В ЧЕРНО-СЕРЫХ ТАТУ

***Проскура С.А.***
*независимый исследователь, США, г. Сан-Диего*

## THE PROCESS OF CONVEYING EMOTIONS AND CHARACTER THROUGH GRADATIONS IN BLACK AND GRAY TATTOOS

***Proskura S.***
*Independent Researcher, USA, San Diego*
DOI: 10.5281/zenodo.19044442

**АННОТАЦИЯ**

Статья посвящена исследованию того, как в черно-серой татуировке осуществляется передача эмоций, характера и внутреннего содержания образа через тональные градации. Рассматриваются принципы работы с диапазоном значений от глубоких теней до мягких полутонов, а также роль контраста, текстуры и плавности переходов в формировании психологического восприятия изображения. Особое внимание уделяется тому, как технические решения мастера – выбор плотности штриховки, направление света, степень проработки деталей и баланс между светом и тенью – позволяют передать эмоциональные состояния, такие как напряжение, спокойствие, драматичность или нежность. Статья раскрывает художественные и психологические аспекты техники black and grey, подчеркивая её потенциал как выразительного инструмента для создания реалистичных, символичных и глубоко эмоциональных татуировок.

**ABSTRACT**

The article is devoted to the study of how emotions, character, and the inner content of an image are conveyed through tonal gradations in a black-and-gray tattoo. The principles of working with a range of values from deep shadows to soft semitones are considered, as well as the role of contrast, texture and smooth transitions in shaping the psychological perception of an image. Special attention is paid to how the master's technical solutions – the choice of shading density, the direction of light, the degree of detail elaboration and the balance between light and shadow – allow you to convey emotional states such as tension, calmness, drama or tenderness. The article reveals the artistic and psychological aspects of the black and grey technique, emphasizing its potential as an expressive tool for creating realistic, symbolic and deeply emotional tattoos.

**Ключевые слова:** черно-серая татуировка, градации тона, эмоции в тату, передача характера, контраст, светотень, художественная выразительность, реализм, психология восприятия.

**Keywords:** black and gray tattoo, gradation of tone, emotions in tattoos, character transfer, contrast, chiaroscuro, artistic expression, realism, psychology of perception.

**Актуальность исследования**. Изучение процесса передачи эмоций и характера через градации в черно-серых тату является актуальным, поскольку стиль black and grey продолжает занимать ведущие позиции в современной тату-культуре, а запрос на эмоционально выразительные и психологически насыщенные изображения постоянно растёт.

В условиях повышенного интереса к реалистичным и символичным татуировкам возрастает необходимость глубокого понимания того, каким образом тональность, светотень и детализация могут влиять на восприятие образа.

Современные стили тату всё сильнее ориентированы на выразительность, реализм и психологическую глубину, что требует осмысления механизмов восприятия мимики, композиции и символики в рамках кожного искусства. Дополнительную актуальность придаёт междисциплинарный характер темы, объединяющий искусствоведение, психологию и культурологию, поскольку татуировка становится значимым элементом идентичности и способом фиксации эмоционального опыта. Поэтому исследование передачи эмоций в тату позволяет глубже понять как художественные закономерности, так и личностные и социальные процессы, происходящие в современной культуре.

Анализ художественных и технических особенностей работы с черно-серыми градациями позволяет не только расширить профессиональные компетенции мастеров, но и способствует развитию визуальной культуры, где татуировка рассматривается как полноценное средство самовыражения и коммуникации.

**Цель исследования.** Цель исследования заключается в детальном раскрытии механизмов передачи эмоциональных состояний и индивидуальных характеристик персонажей или символов в черно-серой татуировке через работу с тональными градациями, контрастом, текстурой и светотенью, а также в систематизации художественных и технических приёмов, позволяющих усилить выразительность и психологическую глубину изображений.

**Материалы и методы исследования.** Материалами исследования выступили примеры современных и классических черно-серых татуировок,

визуальные референсы, эскизы, а также наблюдения за практическими техниками профессиональных тату-мастеров.

В работе использованы методы визуального анализа, сравнение художественных приёмов, изучение технологических процессов нанесения татуировки, а также элементы психологического анализа восприятия изображения. Дополнительно применялись качественные наблюдения за реакцией зрителей на различные типы тональных решений, что позволило оценить влияние градаций на эмоциональную выразительность и характер создаваемых образов.

**Результаты исследования.** Процесс использования градаций в черно-серых татуировках тесно связана с развитием реалистической манеры изображения и стремлением мастеров передать глубину, объём и эмоциональность без применения цвета.

Первые проявления такого подхода можно обнаружить в тюремной и чикано-культуре середины XX века, где мастера были ограничены инструментами и чернилами, а потому работали преимущественно в черной гамме, создавая переходы тонов с помощью разбавления пигмента и варьирования плотности штриховки. Эти графические методы позволяли не только воспроизводить натуралистические образы, но и вкладывать в них эмоциональные оттенки – меланхолию, трагизм, силу, решительность или внутренний конфликт.

С распространением американского реализма и портретной татуировки в 1980-х и 1990-х годах черно-серая техника стала полноценным художественным направлением. Мастера начали активно использовать мягкие переходы, глубокие тени и эффект полутонов, стремясь к максимальной выразительности лица, взгляда или символического образа. Светотень стала главным инструментом передачи характера: мягкие градации создавали чувство интимности и душевности, а резкие контрасты подчёркивали драматизм и напряжение. Благодаря этому стиль приобрёл психологическую глубину и стал восприниматься как универсальный язык эмоций, доступный без использования ярких цветов [1].

В XXI веке черно-серая татуировка превратилась в сложную художественную систему, где эмоциональное воздействие основано на точных визуальных приёмах. Мастера изучают законы академического рисунка, анатомии и фотографии, чтобы максимально достоверно передавать чувства через мимику, направление света, текстуру кожи или фактуру объектов (табл. 1).

Таблица 1

Основные виды черно-серых тату

| № | Виды | Характеристика |
|---|---|---|
| 1 | Традиционные черно-серые татуировки | Классические элементы, часто с использованием черного контурирования и серых теней, как в старой школе. |
| 2 | Реализм | Татуировки, изображающие портреты, животных или пейзажи с глубокой детализацией и реалистичными тенями. |
| 3 | Графика и линии | Абстрактные или геометрические формы, выполненные в черно-сером цвете, часто с минималистичным подходом. |
| 4 | Новые школы | Яркие, но с использованием серых тонов и черных контуров, сочетание стилей и техник. |
| 5 | Татуировки в стиле "watercolor" | Черно-серые с акварельными эффектами, которые добавляют легкости и динамики. |
| 6 | Традиционные восточные мотивы | Черно-серые тату с изображениями драконов, самураев и других восточных символов. |
| 7 | Мандалы и орнаменты | Сложные узоры, выполненные в черно-сером цвете, часто символизирующие гармонию и целостность. |

Развитие качественных чернил, машинок и игл позволило создавать более тонкие градации, что расширило спектр возможных эмоциональных состояний – от нежности и спокойствия до агрессии или внутренней борьбы. История передачи эмоций через градации в черно-серых татуировках представляет собой путь от ограниченных технических возможностей к высокому художественному мастерству, где каждый тоновый переход становится инструментом выражения индивидуальности [3].

Отметим, что в современной черно-серой татуировке передача эмоций и характера достигается сочетанием высокоточного оборудования, улучшенных пигментов и художественных методов, которые позволяют мастерам создавать максимально живые и психологически насыщенные образы.

Современные роторные машинки с регулируемой амплитудой и мягким ударом дают возможность выполнять ровные и чистые градации, обеспечивая плавные переходы между тенями, что особенно важно при изображении лиц, взглядов и тонких эмоциональных нюансов [2]. Разбавленные пигменты разных степеней насыщенности дают мастеру палитру из множества серых оттенков, позволяя формировать сложные светотеневые структуры, передающие настроение – от мягкой задумчивости до напряженной драмы.

Важную роль играют и цифровые методы подготовки эскизов, когда художник заранее моделирует освещение, контраст и глубину, чтобы добиться нужного эмоционального акцента. Технология стекающего градиента и техника stippling позволяют добавить атмосферность, шероховатость или тревожность, а ультра-реалистичный smooth shading используется для передачи спокойствия, внутренней силы или печали через мягкую, едва заметную светотень (рис. 1).

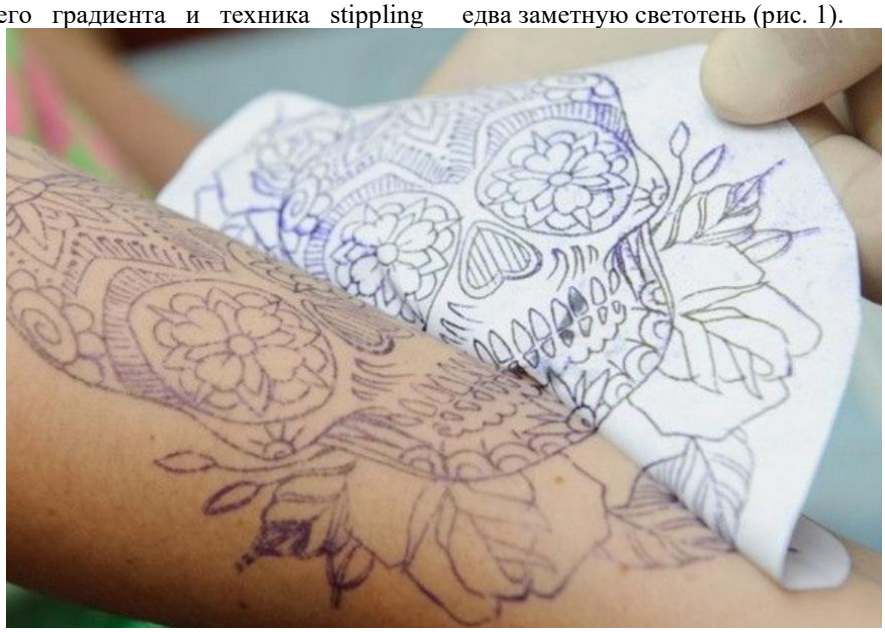

*Рис. 1 – Перенос эскиза тату*

Особое внимание уделяется глазам, морщинам и микро-теням, поскольку они определяют психологический портрет персонажа и дают татуировке ощущение живого присутствия. Благодаря сочетанию художественного опыта, технической точности и развитых инструментов современные мастера черно-серой татуировки способны создавать изображения, которые не просто копируют внешний вид, а передают глубинное эмоциональное содержание, превращая кожу в выразительное повествование.

Растет популярность смещения акцентов внутри композиции: мастера намеренно делают второстепенные зоны мягче и светлее, а ключевые детали – глаза, губы, руки, складки ткани – контрастнее и резче. Такой прием усиливает фокус на эмоциональном центре изображения и делает его читаемым на интуитивном уровне. Использование текстурных техник вроде grain shading, легкого шума или имитации пленочной зернистости также помогает создать атмосферу времени, памяти, ностальгии или внутренней борьбы.

Некоторые художники применяют цифровые нейроинструменты для подготовки эскизов, анализируя микромимику и корректируя тени так, чтобы усилить эмоциональный подтекст – например, сделать взгляд мягче или, наоборот, добавить напряжение за счет более плотных теней под бровями и вокруг носогубной области. Все это делает черно-серые тату не просто изображением, а полноценным эмоциональным языком, где каждая градация серого служит отдельным выразительным инструментом.

Следует подчеркнуть, что передача эмоций и характера в черно-серой татуировке связана с рядом специфических трудностей, поскольку мастер работает только со светотенью, фактурой и контрастами.

Основная проблема заключается в *ограниченности палитры*: отсутствие цвета лишает художника важного инструмента эмоциональной выразительности, поэтому вся эмоциональная нагрузка переносится на точность распределения теней. Любая ошибка в интенсивности серого может изменить мимику, сделать взгляд слишком жестким, уставшим или безжизненным. Это особенно заметно в портретах, где micro-нюансы теней вокруг глаз, губ и носа определяют характер изображаемого человека.

Дополнительную сложность создает *различие* между тем как тень выглядит на бумаге и как она проявляется в коже. Пигмент по-разному ведет себя на разных типах кожи: на плотной дерме тени получаются чище и контрастнее, а на тонкой и чувствительной они могут расплываться или светлеть при заживлении. Это делает прогнозирование финального результата трудным даже для опытного мастера. Многоуровневые градации могут сливаться, особенно если кожа склонна к рубцеванию или грануляции. В результате изображение теряет глубину, а эмоциональный акцент смещается или полностью исчезает.

Еще одна распространенная проблема – *субъективность восприятия эмоций.* То, что мастер считает мягким и спокойным выражением, клиент может воспринимать как грусть или холодность, поскольку эмоциональная трактовка зависит от личного опыта и культурного контекста. Этот разрыв между намерением и восприятием усиливается техническими нюансами вроде слишком жесткого контура, чрезмерно темных теней в глазницах или неправильно расставленных световых акцентов.

Такие мелкие искажения легко превращают живую эмоцию в статичную маску.

Кроме того, черно-серая татуировка сильно зависит от *освещения в момент просмотра*. При слабом свете мягкие полутени исчезают, и изображение кажется плоским, что снижает эмоциональную читаемость. При ярком свете, наоборот, могут проявиться мелкие технические огрехи, ломая целостность эмоциональной подачи. И, наконец, *старение кожи* неизбежно влияет на тату: линии постепенно расплываются, тени светлеют, что искажает первоначальную мимику и делает выражение менее точным.

Передача эмоций и характера в черно-серых тату требует ювелирного контроля градаций, глубокого понимания анатомии лица и постоянного учета индивидуальных особенностей кожи. Любое отклонение на любом этапе – от наброска до заживления – может изменить эмоциональный смысл работы.

По нашему мнению, эффективное решение описанных трудностей связано с комплексным подходом, который начинается задолго до непосредственного нанесения пигмента и продолжается после завершения работы.

Один из ключевых методов заключается в тщательной подготовке референса и детальной визуальной проработке теней. Мастер должен заранее определить эмоциональный центр изображения, акценты светотени и зоны, где для передачи характера особенно важны микро-градации. Использование высококачественных фотографий, предварительное цифровое моделирование и создание нескольких вариантов контраста позволяют точнее подобрать нужную динамику эмоций и избежать случайных искажений мимики.

Второй важный инструмент решения проблем – глубокая работа с индивидуальными особенностями кожи клиента. Профессионал заранее оценивает плотность кожи, уровень увлажнения, склонность к рубцеванию, оттенок и структуру. Это помогает выбрать правильную технику набивки, тип игл, скорость машинки и степень разреженности штрихов. Для плотной кожи целесообразно использовать более резкие контрасты, а для тонкой – мягкие переходы с минимальной насыщенностью, чтобы избежать слияния тонов. Данный подход значительно повышает предсказуемость финального результата после заживления.

Третьим решением является максимально точная коммуникация с клиентом. Перед началом работы мастер должен уточнить, какое именно настроение должно передавать изображение, какие нюансы мимики особенно важны и как клиент интерпретирует те или иные эмоции. Это помогает избежать различий в трактовке выражений лица и свести субъективность восприятия к минимуму. Часто полезно показывать клиенту варианты с разной степенью контрастности, чтобы совместно выбрать наиболее эмоционально точное решение.

Техническое мастерство также играет ключевую роль. Для достижения плавных градаций мастер должен уметь работать по принципу многослойности, последовательно наращивая глубину тени вместо попытки достичь результата за один проход. Контроль давления руки, правильный наклон иглы, равномерное распределение штрихов и умение создавать визуальный объем без чрезмерного затемнения помогают сохранить выразительность и предотвратить нежелательную жесткость эмоций. При этом важно учитывать будущие изменения: грамотно распределенная тень должна выглядеть убедительно и после частичного осветления при заживлении.

Дополнительным методом решения является использование реальных моделей освещения. Перед нанесением мастер может просматривать референс при разном свете или даже моделировать его на планшете, чтобы убедиться, что эмоция остается читаемой вне зависимости от освещения. Такой подход предотвращает эффект плоскости и повышает устойчивость эмоциональной выразительности в разных условиях.

Не менее важна и работа после сеанса. Правильный уход за татуировкой, рекомендации по увлажнению и защите от солнца позволяют сохранить мягкость полутонов, длительность контраста и точность мимики. Это снижает риск преждевременного осветления теней и искажения выражения. Защита от солнца также критична, поскольку ультрафиолет разрушает пигмент и ускоряет его выгорание. Без надлежащей защиты тёмные участки светлеют слишком быстро, что приводит к снижению контраста, расплыванию границ и потере детализации.

В результате мимические акценты, такие как складки, полуулыбки или напряжение мышц, могут стать менее читаемыми и визуально искаженными. Соблюдение рекомендаций по уходу – использование качественного крема, защита от солнца, отказ от пересушивающих средств и механических воздействий – позволяет продлить жизнь эмоциональной выразительности татуировки. Это помогает сохранить чёткость линий, глубину теней и точность передаваемого настроения, поддерживая первоначальный художественный замысел мастера.

Решение проблем передачи эмоций и характера в черно-серой татуировке строится на сочетании художественной подготовленности, технической точности, индивидуального подхода к коже и устойчивой коммуникации с клиентом. Такой комплекс действий позволяет максимально достоверно передать эмоциональную глубину и обеспечить стабильность результата спустя годы.

**Заключение.** Передача эмоций и характера с помощью градаций в чёрно-серой татуировке представляет собой сложный, многослойный процесс, в котором художественное видение неразрывно связано с техническим мастерством и глубоким пониманием индивидуальных особенностей кожи.

Успешный результат достигается тогда, когда мастер способен точно интерпретировать эмоциональную суть изображения, подобрать оптимальную светотеневую модель и реализовать её таким образом, чтобы она оставалась выразительной не только сразу после нанесения, но и спустя годы. Важную роль играют и предварительные этапы –

анализ референсов, выбор контрастности, моделирование мимики, – поскольку именно они формируют основу будущей работы.

Не менее значимым является взаимодействие с клиентом, которое помогает устранить субъективные различия в восприятии эмоций и создать изображение, максимально соответствующее замыслу. Грамотный подбор техники, внимание к типу кожи, умение работать с мягкими переходами и понимание того, как кожа изменяет оттенки при заживлении, позволяют избежать типичных проблем, таких как потеря глубины, чрезмерное затемнение или искажение эмоционального акцента.

В итоге качественная черно-серая татуировка с точной передачей характера – это результат сочетания профессионального анализа, внимательного подхода и кропотливой технической работы. Когда все эти элементы соединяются, татуировка превращается не просто в изображение, а в эмоционально насыщенное произведение, способное сохранять своё выразительное звучание на протяжении долгого времени.

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# THE SIGNIFICANCE OF VERBAL ACTION IN CREATING A ROLE IN ACTING MASTERY

***Serikbayev S.***
*Lecturer at the Temirbek Zhurgenov*
*Kazakh National Academy of Arts*
*Master of Arts*
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**ABSTRACT**
This article discusses the importance of word action in acting.
**Keywords*:*** Acting, word action, character, image, gesture, director, performance.

Action is divided into two types: activity — that is, the subject's spontaneous (independent, free) influence on objective reality — and reaction, that is, activity arising from the influence of objective reality upon the subject. Objective reality, as we can see, must be present in both cases; without it, no activity is possible. However, its mere objective existence is insufficient — the subject must experience it in some way. This lived experience of objective reality is referred to as verbal action. Thus, verbal action in the process of reading a literary text and revealing its stylistic nature constitutes the essence and significance of the actor's continuous professional life or "experience" in creating a stage image. Verbal action is a deep and multifaceted psychological process that depends on the individual characteristics of each artist, especially the actor. It is no coincidence that the fundamental views of the great theorist of acting Konstantin Stanislavski and the distinguished Kazakh theatre scholar Mukhtar Baiserkenev coincide regarding verbal action in the process of reading a text; each sought to profoundly explain its importance in the creation of a stage image. Verbal action in reading a literary text represents a holistic reflection of objective reality that arises from the direct impact of real-world objects upon the human senses. It includes perceiving the object as a whole, differentiating its individual features, selecting informational content relevant to the purpose of action, and forming a sensory image. Verbal action is connected with thinking, memory, and attention, and it becomes integrated into practical activity and communication processes. At the end of the nineteenth century, theatre was closely associated with its own repertoire and with sketch-like plays depicting ready-made facts lying on the surface of life. The lack of thematic depth and authenticity was concealed behind external plausibility and carefully accumulated everyday details. Plays of this period confined actors within superficial life characteristics, encouraging external typification and imitation of speech that emphasized formal traits of character, worldview, or nationality. The "truth" of such theatre was theatricalized; its realism and stage expressiveness were distinguished by conventional speech and memorized vocal modulation. Traditional methods of expressing emotion, along with codified gestures and tonal patterns, were transmitted from generation to generation. Great artists, through the force of their talent, broke free from outdated clichés and demonstrated models of passion, vitality, experience, and naturalness. They revealed the living breath of truth and power that served the realization and disclosure of real life. However, in the speech practices of Russian theatre — even during the formation and flourishing of realist art marked by the names of Mikhail Shchepkin, Alexander Ostrovsky, Pavel Mochalov, Maria Yermolova, Mikhail Sadovsky, and Alexander Lensky — by the end of the nineteenth century clearly defined formal clichés had nevertheless emerged. This indicated the lag of art behind the demands and needs of living reality. The intonational techniques of stage speech increasingly entered into deep contradiction with the evolving artistic tasks facing twentieth-century theatre, which sought to respond to the demands of its time and to rethink its expressive means accordingly. As Anatoly Lobanov rightly observed: "There was truth in the Maly Theatre. Let us say Gogol appeared and spoke his truth — and suddenly it became unbearable to listen to people on stage speaking in the pre-Gogolian manner. The Art Theatre arrived and proposed a different rhythm and manner of speaking in life, and beside it the speech style of the Maly Theatre began to seem, so to speak, an anachronism." Declamation, pathos, and theatrical "stamps," along with everyday conventional markers, became obstacles to the development of theatrical art. A refined theatrical consciousness once again intensified its demand for truth in stage speech — truth corresponding to contemporary life, to its needs, anxieties, and emotional experiences, and to the authenticity of life on stage. At the end of the nineteenth century, the Music and Drama School of the Philharmonic Society played a special role in shaping new approaches to actor training. Within its walls, in 1891, at the special invitation of Alexander Yuzhin, Vladimir Nemirovich-Danchenko began teaching dramatic art to actors. Nemirovich-Danchenko worked at the school with great enthusiasm and dedication for more than a decade, until 1901. During this time, he trained several generations of actors, including such major theatre figures as Olga Knipper, Ivan Moskvin, Vsevolod Meyerhold, Nina Litovtseva, Maria Savitskaya, and Sofia Khalyutina. His pedagogical activity at the Philharmonic School possessed immense and transformative significance for the Russian theatre school. During these years, his creative method took shape, as well as his approach to resolving the fundamental artistic and methodological issues involved in training an actor of high culture, genuine stage truth, and elevated civic consciousness. Nemirovich-Danchenko regarded theatrical pedagogy as an entirely new approach to actor training and as a means of creating a new theatre. As a playwright, writer, director, and public figure, he formulated the tasks of "initiating into art" as follows: "To preserve individuality, to bring a 'spark' into life, to assist its development, to

work constantly with human material, to saturate it with one's best ideas — this is the seed of theatre, its deepest and most captivating essence…" Before Nemirovich-Danchenko's arrival at the Philharmonic School, instruction in theatrical creativity was far from satisfactory. He later recalled: "The educational significance of the theatre school was completely disregarded; it was impossible to convince anyone of the importance of voice production, diction, flexibility, dance, fencing, and general educational courses." The traditions of great actors had been forgotten, and no systematic training existed. Pedagogy was limited to preparing roles and developing techniques for expressing emotions. The pedagogical position closest to Nemirovich-Danchenko's principles and demands was that of Alexander Lensky, who worked with rare dedication at the Maly Theatre School. Nemirovich-Danchenko and Lensky, discussing both general and specific issues of theatrical pedagogy in detail, sought to share their explorations, experiments, and achievements with one another. With exceptional persistence, Nemirovich-Danchenko searched for methods and means to combat the inertia of theatrical art and pedagogy, as well as routine formulas and clichés. He criticized the theatre school for deriving not from life, but from stage stereotypes — for teaching the depiction of external aspects of life, the repetition of emotional schemes, and the memorization of theatrical clichés. Therefore, he insisted with particular force on the radical restructuring of the system of theatrical education. Nemirovich-Danchenko rejected the old practice of preparing roles; he denied technology for technology's sake, and reading for reading's sake. He sought ways to educate an artist capable of living on stage, of revealing the character of an image, of sensing truth, and of thinking and creating independently. As he wrote: "Above all, I seek authenticity and a serious artistic foundation. The professor's task is to teach students to think about the characters they portray and to show them how a role should be perceived." Even at that time, Vladimir Nemirovich-Danchenko believed that in order to free the actor's art from falsehood and cliché, simple and truthful speech was essential. A considerable part of his pedagogical work was therefore devoted to cultivating the actor's speech — its expressiveness, brightness, and simplicity, as well as its clarity and richness. This can be observed in the detailed substantiations of his teaching program, in his requirements concerning "tone" and diction, and in his notes on individual students, where he consistently evaluated their data and achievements from the standpoint of stage speech: "Knipper: noble diction, honest tone, very intelligent declamation. Savitskaya: tone clear in the sense of sincerity and beauty, not entirely precise, yet free from vulgarity and coarseness." In his work on tone, Nemirovich-Danchenko paid particular attention to such concepts as artistic taste, vitality, simplicity, lightness, richness of imagination, verbal action, the раскрытие stylistic nature of the text, correct understanding of the role, and perceptiveness. In his work on diction, he emphasized the voice, the beauty and strength of sound, the ability to command it, purity and clarity of articulation, authenticity, and variety of intonation. In working with the word, he demanded not merely technical excellence in pronunciation, but above all the naturalness and vitality of speech, the accurate transmission of thoughts, feelings, and moods grounded in comprehensive analysis of the material and deep psychological interpretation of its content, as well as the revelation of the stylistic nature of the text. We find confirmation of this in his directorial practice, for example in his production plan for Julius Caesar (referring to the staging of Shakespeare's tragedy). Nemirovich-Danchenko focused closely on the logical structure of the text. He carefully analyzed the semantic and intonational character of each phrase in Brutus's monologue, relating it to the character's personality, actions, objectives, and thoughts. By answering questions such as, "Why does the character speak in this way at this very moment, and not differently?", he took decisive steps toward understanding verbal action through uncovering the stylistic nature of the text. Not only professional training, but also the comprehensive cultivation of the actor's personality constituted the essence of his pedagogy. This marked a new stage and a significant advance in theatrical education. In the struggle for a new theatre that reflected life — for social and artistic truth, and for a new type of actor — the struggle for the living, active word occupied a special place. "The old template had to be broken… In order to free ourselves from the conventional mastery of transmitting stage experience… it was necessary to shake off the entire shell of conventions in intonation and vocal modulation, to achieve the highest simplicity of theatrical speech, yet without rendering it dull, pale, or colorless, and without depriving it of lyrical shading. The simplicity of verbal action does not mean excessively simplified speech as in everyday life." Understanding stage speech as a mode of being and communication became one of the most important aspects of the new theatre's aesthetics. Naturally, this development was made possible by new dramaturgy. Above all, one may mention the plays of Anton Chekhov, although his works were not staged at either the Alexandrinsky Theatre or the Maly Theatre at first. The renewal of dramaturgy, striving to reveal the depth and substance of life, was directly connected with progressive literature. The dramatic novel of Fyodor Dostoevsky, the dramaturgy of Leo Tolstoy, and the plays of Chekhov — all sought to portray the human being in the full complexity of spiritual life. They revealed not only objective connections expressed in textual structure, but also deeper additional meanings and the stylistic nature of the text. From the understanding of subtext arose verbal action. From their very first attempts to create a new theatre, Konstantin Stanislavski and Nemirovich-Danchenko showed a deliberate and profound interest in theatrical speech traditions. Stanislavski singled out Pavel Mochalov from the entire theatrical world rich in talent as a genius who addressed epoch-making problems. His aspiration toward genuine experience, the unexpectedness and spontaneity of verbal action, the naturalness of speech, his capacity to reveal inner life and the stylistic nature of the text — more than the declamatory manner of the old romantic school or the deliberately exaggerated everyday speech obscured by an impenetrable shell — deeply convinced audiences and attracted the emerging new theatre. The formation of the artistic method of the Moscow Art Theatre was characterized

by reflection on the living word, by the search for ways to achieve the highest simplicity of speech, and by a complete rejection of traditionally canonized stage verbal action. In the search for the "truth of feeling in given circumstances," the theatre sought a new, contemporary manner of speech. However, the revolution in stage speech was not only about rejecting everyday similarities, old speech canons, or the usual conventions; it was also about the very idea of creating truth in stage interactions instead of using literal words. Behind the text lay the world of thoughts, viewpoints, and emotions that underlie human behavior and give rise to words in life, as well as its stylistic nature. The emphasis on inner action and inner life, rather than the external, revealed the causes and connections of thoughts and words, generated their flow, and brought to light the inner forces that determine the life of speech, reflecting a desire to uncover the text's stylistic nature. This idea was manifested in the 1898 production of The Seagull. Everything in the play served to reveal this inner life: the free mise-en-scène that obeyed no tradition, the flow of life continuing behind the stage, the sound of rain, immersing the characters in their everyday worries, distant emotions, and sudden pauses. The manner of speech in the performance was new because theatrical, conventional, elevated speech disappeared. The liveliness and authenticity of speech arose not from external signs of reality, but from the truthfulness of behavior, understanding the thoughts, and grasping the stylistic nature of the text. The laws of reading a stage text had long been known, but they did not apply in the new theatrical processes. This does not mean that simple and vital speech laws did not exist. On the contrary, "the ability to speak simply and beautifully is a science with its own rules." But the theater did not know these rules. They had to be carefully studied and mastered. The entire creative practice of the founders of artistic theater was connected with discovering the true organic laws of living speech on stage. Theater specialists understood that one should not "act" any emotion, mood, stance, word, style, or image; instead, the stylistic nature of the text had to be revealed and realized through the effectiveness of speech. Behind the protest against artificial speech was always respect for the author's word and the desire to convey it to the audience accurately and convincingly. Yet while valuing the word, just as an artist judges its color and tone, or a musician evaluates sound, the founders of the new theater considered it an unchangeable truth: the actor's word had to exist on the same level as all elements of the creative process, arising naturally, organically, as a direct result of inner life. The theater persistently sought methods to work with speech that would correspond to the entire actor's system. Adapting speech for direct stage expression was a completely different process. The idea of returning to The Seagull arose to draw the actor's attention to particular details: "a match and a burning cigarette in the dark, powder in Arkadina's pocket, Sorin's blanket, a comb, a cuff, washing hands, drinking water, and so on… The actor had to be trained to perform these actions so that speech would become easier." Sometimes the striving to make speech lifelike and natural stemmed from a heightened interest in speech characteristics, where speech became a means for the theater to create the truthfulness of the character's behavior. This led to ethnographic precision in paying attention to speech features and details in texts such as L. Tolstoy's The Power of Darkness and M. Gorky's The Lower Depths, and in capturing the stylistic nature of the text. Yet for theater directors, the most crucial adaptation for living speech appeared to be the actor's organic life activity. K. S. Stanislavski, reflecting on the production of L. Andreyev's The Life Drama, wrote in the chapter "Revealing Familiar Truths" that he had kept actors away from rigid mise-en-scène decisions. Stanislavski feared that mise-en-scène could distort the inner process, conceal it, push it into the background, or even replace living behavior with "muscle memory." Therefore, he "eliminated the mise-en-scène." In 1909, Stanislavski staged I. Turgenev's A Month in the Country using a strictly static approach. M. V. Dobuzhinsky's remarkable set design, with its enclosed depth, symmetrical stage images, and carefully indicated transitional passages, was cut away. All the director's attention was focused on the inner process. His detailed commentary revealed what lay behind each line, what performers should feel and understand. At that time, the principle he called "illumination" was extremely important: a sequence of actor tasks, based on careful analysis, ensured physical comfort and revealed the subtext of speech. In Stanislavski's directorial notes, there is clear and general guidance showing that the content and stylistic nature of the text is revealed through subtext, which produces the effectiveness of speech. In the second act of this play, the text reads: Natalya Petrovna: "No, please, do not shoot toward the garden. Save this poor bird… Moreover, you will startle your grandmother." K. S. Stanislavski (p. 19) noted: "These words should not be understood literally; the point is that there seems to be an additional meaning or subtext in them, like 'I love you,' 'I want to be with you.'" His directorial notes also contain purely technical instructions: "speaks loudly" (p. 24), "the speech manner and tone of the teacher, that is, a lady of the style of that time" (p. 30), "silent, as if hiding from others" (p. 35), "speaks very simply and quietly" (p. 35), "I am in love, simply, slowly, as if reading the letters of this feeling" (p. 36), "at a fast pace" (p. 37). These instructions are few, and all are aimed at revealing subtext, the stylistic nature of the text, how to convey it to the audience, how to express the effectiveness of speech, to enhance and refine physical well-being, and to adapt performance organically. Vladimir Ivanovich Nemirovich-Danchenko and K. S. Stanislavski understood that seeking the life truth of a word, uncovering the stylistic nature of a text, and achieving it were not easy tasks. Even though Stanislavski disliked the study process when working on A. P. Chekhov's plays, he engaged extensively with hexameter. The actor's vocal capabilities—their beauty, clarity, and sound potential—were important for Nemirovich-Danchenko in addressing purely creative challenges. At the Moscow Art Theatre's stage, in the premiere of Three Sisters, the role of Olga was performed by the highly captivating actress M. G. Savitskaya. Savitskaya, with her uniquely beautiful voice that had once started with Antigone, played the elderly daughter with heartfelt delicacy. Her

beautiful voice allowed Nemirovich-Danchenko to perceive the poetic nuance needed to convey Chekhov's language and the stylistic simplicity inherent in the author's text. After Savitskaya passed away, the actress O. Butova aspired to play Olga. Despite recognizing Butova's abilities and talent, Nemirovich-Danchenko did not deem it appropriate to assign her this role. In a letter to Shchepkina, Butova admitted: "Nemirovich-Danchenko spoke wonderfully. He said everything that could be said to an actress, but overall, portraying Olga is not my task; he said my talent is limited… My voice is my greatest obstacle." From production to production, from role to role, Nemirovich-Danchenko's advice, his notes on speech manner and nature, and guidance on "finding the character's speech" accumulated. In a letter to M. S. Stanislavski (1902), discussing the role of Satin in M. Gorky's The Lower Depths, Nemirovich-Danchenko emphasized the need to develop a new technique: "Develop rapid, effortless speech without pauses. Words must flow from your mouth easily and continuously." After the Great October Socialist Revolution, an integrated approach emerged in the creative practice of the Moscow Art Theatre: speech was considered the most important component of a performance; stage speech became an internally managed process dependent on the speaker's objectives, circumstances, relationships, individual characteristics, and psychophysical condition. M. O. Knebel recalled: "To create a living character, generate the effectiveness of speech, and reveal the stylistic nature of the text, actors needed versatile, varied, and expressive speech. This was an essential condition for working on the production." The living soul of a phrase is sensed internally but expressed with taste. Work on subtext and acting technique are closely interconnected. Choosing breath, lightness, subtlety, rhythm, and the expressiveness of sound requires developing vocal technique and mastery, while simultaneously uncovering the effectiveness of speech and the stylistic nature of the text in the creative process and reading. By the late 1930s, Nemirovich-Danchenko's key methodological principle was clearly articulated: "A word arises from the seed of the actor's psychophysical character in the role." He explained this inner connection as follows: "An actor achieves the right path in creating a stage image by understanding the thinking, character, and stylistic nature of the text of the character he or she embodies. From this, movement qualities and speech manner, as well as the effectiveness of speech, naturally arise." While working on Three Sisters, Nemirovich-Danchenko consistently returned to the idea of emotional ignition and the actor's physical well-being. To give birth to a word, one must "plant the emotional seed," and for this, all behavior, thoughts, and feelings must adapt to the stage situation, giving rise to the effectiveness of speech. "This was the most important aspect for me during preparation," he said. An actor's mood develops from understanding the typical traits, complexities, and contradictions of the characters in the play, their relationships with people, their individual characteristics, life experiences, profession, biography, and the unity of their personal qualities. Nemirovich-Danchenko moved from the character, lifestyle, thought, temperament, and physical and behavioral state to the actor's speech. "Begin to imagine what he is like. Perhaps your speed of speech is too fast for Chebutykin? He is slow, filled with life experience, and therefore cannot speak quickly" (Gribov – Chebutykin).

"When Olga walks around the room, she communicates all of this" (p. 51, 181) (Elanskaya – Olga). He further instructed Elanskaya: "Olga is the eldest in the house; she is not sentimental, but impressive; she is the future head of the gymnasium; she speaks clearly… One must endure such simplicity to speak more precisely…" To Georgievskaya – Natasha: "…because there is coldness in her inner world… therefore she speaks firmly, harshly, and with authority." We will not continue with examples, but we note the ideas of Nemirovich-Danchenko and Stanislavski: their thoughts deeply connect all aspects of speech with a person's individuality, personal and emotional traits, and are among the most important and forward-looking from the perspective of understanding the laws of modern speech communication. The development of speech art in the Soviet theater was based on strengthening the realist traditions of the actor's school and on cultivating civic consciousness and the social significance of theater. Before the Great Patriotic War, Soviet theater was distinguished by highly professional mastery of stage speech. Its traditions were shaped under the influence of the classical Russian school of speech, while creative approaches were renewed through Soviet theater practice. The culture of theatrical speech was enriched with sounds, rhythms, shades of socialist reality, intonations, expressiveness, and the style of Soviet dramaturgy. An important factor in the formation of the Soviet school of speech was the creative influence of the leading Soviet directorial trend: for example, the work of A. I. Dikiy, A. D. Popov, N. P. Okhlopkov, A. M. Lobanov, and Yu. A. Zavadsky. Alongside K. S. Stanislavski, who considered the enactment of the word on stage—that is, speech effectiveness and revealing the stylistic nature of the text—as a crucial element, Vladimir Ivanovich Nemirovich-Danchenko's influence was also significant. For actors in the 1920s–1940s, speech and voice were the primary focus. Actors such as B. V. Shchukin, M. F. Astangov, M. I. Babanov, and N. M. Mordvinov stood out for their exceptional voices, intelligent, free, and expressive speech, nuanced articulation, and musicality. Beyond this, behind each word there lay a real, bold, and confident contemporary feeling, deeply and passionately engaged with the purpose at hand. The brightness and fullness of the voice, the expressiveness of diction, the clarity and scale of speech, its carefully considered and confident expressiveness, unique personal intonation, dynamic range, and tempo-rhythm—all these were distinctive features of Moscow Art Theatre actors' manner of speech. The actors' speech created a special atmosphere imbued with the breath of stage reality. Yet this was not only the actor's truth; it was also a purified, stylized, and heightened truth born from adherence to the author's manner, an expressive and image-based reality. During the Soviet period, Nemirovich-Danchenko's directorial work crystallized the principles of creating living speech on stage. Plays, requiring a synthesis of life, social, and theatrical truths, demanded the director's most

engaged and exacting work with the word. The specificity and truth of stage speech for Nemirovich-Danchenko lay first and foremost in precisely understanding and clarifying the author's style. How the author's idea should be expressed, and by what expressive means it could be conveyed, was equally important: "…you only use the author's idea, subordinating their vocabulary to everyday speech. The author's individual intonation always lives in a good play… If we do not hear it, we cease to have the 'author's theater.' Then we limit ourselves to content alone, neglecting expressive complexity. Then it no longer matters how it is written, and creativity, art, stops. This leads to a general decline in the theater. Only a 'general simplicity' remains." Everyday, life-like speech, in the works of A. Ostrovsky, M. Gorky, A. Chekhov, L. Leonov, and N. Pogodin, was sublimated behind the text, in the author's style and in the actor's speech, through the expressive plasticity of words, tonal relief, boldness and clarity of intonation, and rhythmic articulation. Actors complemented and revealed the speech traits of the environment provided by the author, carefully and lovingly using pronunciation, dialect, emphasis, and individual speech characteristics. Naturalness was combined with remarkable expressiveness, musicality, purity, fullness, and variety. Their speech reflected the requirements of the time: its aesthetics, rhythm, and orthoepic and phonetic culture. The best Soviet actors of the 1920s–1940s were exceptional in both individuality and manner of expression, collectively representing the speech art of their era. K. S. Stanislavski and Nemirovich-Danchenko, defining ways to create life on stage, developed an approach to living stage speech based on the effectiveness of words, grounded in the precise alignment of actions, imagination, and stage tasks, and in absolutely exact communicative means. Stanislavski's system began forming before the revolution (at least from 1907), rooted in early theatrical experiments. Yet it was during the Soviet era, when its guiding principles were articulated and by the 1930s, that the Stanislavski system solidified as a creative method of Soviet theater. Like any living phenomenon, it developed and evolved through the theater's life experience and specific creative conditions. If the foundation of this system is a super-task, the theory of action, and stable values, if the ways to create "the life of the human spirit" and the actor's lived experience serve as an objective method of creativity, then expressiveness, external technique, and representational methods are naturally flexible and changeable. The measure of truth, realism of stage speech, and the culture of speech are determined by contemporary reality, its requirements, norms, and aesthetic and ideological standards. The fundamental rupture in the tradition of stage speech before the war was marked by the Great Patriotic War, which transformed the entire life of theater and decisively affected stage speech. Humanity went through suffering and heroic trials; the meaning of tragedy was revealed sharply and harshly, and spiritual values were expressed with unprecedented intensity and power. Understanding humanity's place in the postwar world required civic maturity and natural authenticity in depicting life, abandoning embellishment of human relationships. Traditional forms of external acting technique hindered performance: imitation, prepared intonation, memorized pauses and emphases were increasingly felt, becoming standardized for decades, and thereby often disrupting the living processes of truth. The general accepted tradition of theatrical speech declined in representing the essence of life phenomena in the best postwar Soviet plays. Artists seeking a new aesthetic ideal found in theater, behind simple exterior speech, the concrete, everyday matters that revealed the inner life of characters. Of course, this was speech that served "only itself"; understanding its content and the inner life of existence on stage could occur only under high creative conditions, when directors and actors could reveal deep, living processes. At that time, in Sovremennik theater productions, real life was conveyed on stage clearly and sincerely. The everyday similarity of intonation in G. A. Tovstonogov's bold directorial decisions created high tension in events, while the truth of feelings and thoughts in A. V. Efros's productions was lived and performed authentically by remarkable actors. The experience of young Sovremennik actors, born within the walls of the Moscow Art Theatre and its school, embodied the realism of the Moscow Art Theatre, the immediacy and authenticity of contemporary relationships, and a thirst to speak in a living, modern language reflecting the realities of the time. In creating a new theater, O. N. Efremov had to address the full range of civic, human, and artistic concerns. Solving these issues required a new drama that could depict the people's new life experience, in which young actors could portray the destinies and lives of their contemporaries and peers deeply and fully. Perhaps for this reason, V. Rozov's Forever Alive became one of the theater's most compelling, daring, and authentic productions. Themes of war, life, love, loyalty, and selflessness were presented in a way that was heartfelt, relevant, and innovative. Young actors approached each performance as a personal struggle. They lived through their characters' lives and were infinitely truthful. The vivid structure and stylistics of Rozov's highly cultured play found expression in the everyday reality of life and in the authenticity of the actors' speech. Stage speech held a unique place in the aesthetics of the new theater. By setting clear artistic goals, Efremov taught actors the skill of conveying the final objective through the unfolding of each role. Emerging from living, active stage behavior, actors explored how each character would conduct themselves relative to the pressing purpose of the performance. The question "Why?" was never abandoned throughout the role work. Secondary but fully realized truths—the emotional precision of inner life, the absolute reliability of movement and gesture—all began with, and gained momentum from, the word. Speech on stage was neutral in phonetic and stylistic qualities. This was reinforced by the author's everyday vocabulary and the credible ordinariness of the play's characters. The actors of the Moscow Art Theatre were trained in drama, and its style and imagery significantly shaped the theater's manner of speech. Questions of speech distinctiveness and speech characterization revealed the personal traits of character and role, playing a major role in their work. For the actors in Efremov's theater, most of whom were portraying their contemporaries, the role was above all the "I" of a person placed in an unfamiliar

situation. Efremov developed actors' abilities through large, cohesive episodes, moving through entire segments of a role toward the central objective. In semantically concentrated episodes, speech could carry weight and significance, with the word taking precedence. In Rozov's Forever Alive, the theater's manner of speech appeared credible and vivid. For example, Veronica (A. B. Pokrovskaya) runs into the room hopelessly and flustered, grabbing tables, chairs, and cabinets, as if seeking a support to rescue. From the torrent of grief carrying Veronica, only the essential words emerge, held as if by someone drowning in water. In the speech of the best actors of the 1950s–1960s, words were delivered in a new, living manner, growing from a deep interplay of elements. However, the power that came from the truth—its resemblance to reality, intellectual assimilation, and precision of action—could, if reduced to mechanical replication, immediately turn against itself. This is a natural occurrence. Everyday speech, as in life, conveys no meaningful process, yet in imitation it easily takes root and creates the illusion of truth. The desire to remove layers of resemblance and habit sought to cleanse stage speech and acting skills from clichés, to search for new, even deeper ways to depict life on stage. Yet in seeking living speech, while avoiding theatrically stylized pronunciation, only the superficial features of everyday speech developed: displayed words, quiet speech, "under-delivered," calm, monotonous, "non-actor" voices, slow articulation, incompleteness, and gaps in sound. A whole recent period of theater practice became closely associated with "whispering realism," self-serving expression, and mannerless, dim, indistinct, theatricalized sentences. Many qualities of theatrical speech came to be labeled as mere theatricality. Well-prepared voices, polished speech, carefully measured sentences based on grammatical logic, exact pauses, speech accents, rising and falling intonation—all hid uncertain, artificial, lifeless content. If declamation was the hallmark against which early 20th-century fine theater fought, by mid-century the hallmark had become quiet, gray, and muted speech. This conventionalized, external, imitative method, canonized as part of acting technique, led to a crisis in the art of stage speech and affected the most important and profound inner qualities of acting. This phenomenon, often considered speech neutrality, reflected a significant decline in the theater's speech culture. "There are now two extreme situations regarding the word," wrote G. A. Tovstonogov. "On one hand, the pursuit of a modern approach to being on stage, realism, and fighting declamation has led to neglecting theatrical speech through deliberate word play. This undermines the nature of our art… There is another old problem. This is the actor turning the word into a self-sufficient element, after which the effective process stops, and speech begins in isolation. In this case, the nature of theater is also disrupted." In searching for a new, living, and more organic way for the actor to inhabit a role—regardless of approach—if it is aimed at deepening our ideas about life truth on stage, the word is placed in the foreground. In other words, all the subtlety of experience is represented and rendered visible. If the rejection of the word is merely an attempt to mimic contemporary life, the very meaning of theater disappears. Unfortunately, the formal methodology of creating everyday-like word effectiveness, speech, and whispering became commonplace. Directors' primitiveness, the inability to translate the super-task into action, and the neglect of the expressive potential of the author's language often led to imitation of the worst examples of poor, quotidian speech, rather than portraying vitality authentically and integrating it with speech and stage realism. Striving to speak words well, loudly, and clearly is not effective if it does not conceal the genuinely internalized, purposeful, and living relationships. Soft murmuring and emphatic scolding are two sides of the same coin. Stage speech today demands deeper and more subtle methods to reveal the actor's inner life and delicate inner technique, imposing special requirements on direction. The effectiveness of speech on stage, contemporary speech, and its distinctiveness can be assessed in direct connection with truth and with the theatrical processes of the last decade. Attention to "today's" vibrant speech on stage depends on several factors, the most important being the characteristics of contemporary art, its principles, and the refinement of our ideas about its measures. Radio, cinema, television—any mass medium brings the actor closer to the audience. Modern technologies have entered theater life directly, but without exerting overwhelming influence. Sound and image are very close to the viewer; the actor's art becomes part of everyday life, of everyday reality. Norms for perceiving living speech, its height or ordinary scale, theatricality or simplicity—all underwent profound change. A wide audience, varying in education and cultural background, remained in constant contact with the actor's art. Under this influence, the audience's artistic taste and aesthetic perception developed, as did their understanding of the "resemblance" of human behavior in real life and the actor's behavior on screen and stage (either heightened or dimmed). Another crucial factor was the ability to perceive stage reality and the effectiveness of speech. The skill of recognizing realistic behavior and hearing living speech was honed. Despite changes in perception and the proximity of daily life in theater, the criteria for live interaction on stage, as opposed to television or cinema screens, remained uncompromised. The effectiveness of stage speech in contemporary theater is influenced not only by the director's concept for a production but also by the development and transformation of the actor's art itself. The demand for natural, conversational language in today's theater is not merely legitimate—it is essential. The key question is how to understand and achieve this conversational speech. K. S. Stanislavski and V. I. Nemirovich-Danchenko considered the simplicity and naturalness of spoken language an inseparable and even defining element of theatrical art. Although Stanislavski noted, "Most people speak poorly and crudely in everyday life…," life itself served as a standard for him in measuring stage speech and verbal action. He asked, "Have you ever heard extremely simple speech on stage or in life—without extraordinary vocal effort, without rising or falling dramatically, without excessive stretching of sound intervals, without complex phonetic figures or intonational patterns? De-

spite the absence of all these methods to intensify expressiveness, very simple speech often produces an incomparable effect through its logic, coherence, clear grouping of words, structural organization of phrases, endurance of delivery, clarity of thought, and precision of lexical expression." Stanislavski's reflections and research in speech and voice were aimed at finding the optimal ways to cultivate stage speech as true, living, and organic speech. The central principle of such speech was, naturally, verbal action. "In life, people always speak with some goal, task, or necessity, always aiming to accomplish something through their words." On stage, verbal action arises from actively perceiving and engaging with the stylistic nature of the work, thinking and feeling, and understanding the author's text in a particular way. It is realized through the author's words, as the performer engages with the literary, stylistically refined language of the writer. This language exists as the character's speech—specific, individual, and unique verbal action within the role. Simultaneously, lexical choice, stylistic form, punctuation, and all other expressive tools are closely interconnected, conveying the vividness, emotional content, and stylistic character of the role material. Only in this structure do the typical qualities of the author's speech fully emerge. Theater, in turn, transforms the written speech of the play into living, oral expression and verbal action. It is important to note that while literary written language has been studied extensively for a long time, systematic research into verbal action began only at the end of the 1950s. In recent years, dedicated studies on verbal action have highlighted its distinctive qualities, comparing it not only with written language but also with other forms of spoken speech. Verbal action is one of the oral speech styles with its own functions and properties. Its defining features are the "specific environment of the speakers," and its content is determined by the "interests of communication at the given moment." Conversational speech is primarily dialogical, unrehearsed, and always directly dependent on the interlocutor's reception. In verbal action, intonation serves as a form of being—it plays a primary, leading role. To understand the action, task, evaluation, and relationship—in other words, the meaning—intonation is critical. Stress, pauses, and other nonverbal communication tools such as gestures and facial expressions sometimes replace detailed verbal information, allowing ambiguity, continuity, or incompleteness in speech. Researchers of verbal action have noted and identified its unique properties, distinguishing it from the intonation of other functional spoken styles. Its key characteristics—pace, intensity, pauses, and tension—vary infinitely and resist formalization or schematic patterns. Variations depend on the speaker's objectives, the communicative situation, and personal traits. Rapid, slow, relaxed, or unhurried speech occurs side by side, with careful, nearly syllabic articulation and sometimes indistinct endings or omissions of individual sounds. The spontaneity of live, direct speech produces natural pauses and silences. In concrete situations of verbal action, sentences often form continuous wholes, skipping necessary syntactic pauses and featuring non-syntactic, psychological, or physiological breaks. The main features of intonation in oral speech can be summarized as follows:

1. Intonation exhibits significant contrasts—from minimal, almost "colorless" everyday cues in meaning, clarity, and expressiveness, to highly stylized, maximally loud, and clearly expressive intonation in formal speech.

2. The precision of intonation varies, using very high and low tones, abrupt drops, and rises. Oral sentences are marked by alternation of stressed and unstressed elements, which defines both speech production and perception. Smooth alternation of rising and falling tones creates rhythm and eliminates monotony typical of codified literary language.

3. Verbal action is highly emotional ("affective speech is the best way to convey your thought to the interlocutor"). Sustained vowels are a characteristic method.

E. L. Nosenko highlights the role of the "vocal channel"—voice and breathing—in conveying emotional information. Key aspects include:

1. Pronounced deviations in fundamental frequency and intensity of speech signals.

2. Sudden changes in overall speech tone, with increased pace through articulation of speech units.

3. Increased speed of articulation (absolute speech speed).

4. Variation in the duration of the actor's or reader's reaction to cues.

5. Articulatory errors (blurred pronunciation), sometimes transforming speech into singing.

6. Increased number of words distinguished by logical stress.

7. Greater frequency of grammatically and logically incomplete phrases compared with normal speech.

Theater researchers emphasize that incomplete and indistinct articulation in verbal action can hinder comprehension of stage imagery. This ambiguity arises from quantitative and qualitative reductions in vowel sounds, shortening of vowels, loss of consonants, and loss of word beginnings, endings, or connections. All these phenomena are associated with very low intensity and slow articulation. Reduced clarity and imprecision in diction are thus natural features of living speech. Negligence in verbal action in everyday life is compensated by factors such as:

- The speed of interaction with partners
- Nonverbal means of communication
- Opportunities for repetition and correction
- Conversational habits with the interlocutor
- Lack of need for exhaustive phonetic clarity and articulation details for the purposes of dialogue

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# ECONOMIC SCIENCES

## FISCAL DECENTRALIZATION, PUBLIC INVESTMENT, AND REGIONAL INCOME CONVERGENCE: EVIDENCE FROM UZBEKISTAN

***Egamnazarova G.***
*Researcher of Tashkent State University of Economics*
*https://orcid.org/0009-0009-6406-1789*
DOI: 10.5281/zenodo.19044467

**ABSTRACT**

This paper examines whether fiscal decentralization and public investment contribute to regional income convergence in Uzbekistan between 2019 and 2025. Using a balanced panel dataset covering 14 administrative regions, we estimate Fixed Effects and β-convergence models to assess the effects of capital expenditure, social transfers, fiscal retention mechanisms, and employment growth on household income dynamics. Results indicate that capital expenditure demonstrates strong positive elasticity with respect to income growth and supports conditional convergence across regions. Social transfers significantly reduce poverty but display weaker long-term growth effects. Regions retaining higher shares of locally generated revenues experience stronger employment expansion and accelerated income growth, suggesting that fiscal autonomy enhances development outcomes. The findings contribute to regional development and fiscal federalism literature by providing empirical evidence from a post-transition Central Asian economy undergoing institutional reform. Policy implications emphasize performance-based intergovernmental transfers and investment-oriented decentralization mechanisms to reduce spatial inequality.

**Keywords:** regional convergence; fiscal decentralization; public investment; spatial inequality; poverty reduction; Central Asia.

**Introduction**

Regional income disparities remain a defining challenge in emerging and transition economies. Despite sustained national growth, uneven capital accumulation and institutional heterogeneity often produce persistent spatial inequality.

Fiscal decentralization has emerged as a central policy instrument to address such disparities. Theoretically, decentralization enhances allocative efficiency and responsiveness (Oates, 1972), yet empirical findings remain mixed regarding its impact on regional inequality (Rodríguez-Pose and Ezcurra, 2011).

Uzbekistan presents a unique case. Since 2019, the country has implemented:

- Expansion of capital expenditure,
- Reform of intergovernmental transfers,
- Retention of surplus revenues at local levels,
- Employment-linked subsidy programmes,
- Strategic poverty reduction initiatives.

Between 2021 and 2025, poverty declined from 17% to 5.8%, while household incomes more than doubled in nominal terms. However, regional growth trajectories diverged significantly.

This paper addresses three research questions:

1. Does capital expenditure promote regional income convergence?
2. Do social transfers generate sustainable growth effects?
3. Does fiscal autonomy enhance regional development outcomes?

The study contributes to regional development literature by introducing new empirical evidence from Central Asia.

**Theoretical Framework**

**Keynesian Multiplier Effects**

Public capital expenditure stimulates regional economic activity through demand and supply-side channels (Keynes, 1936). Infrastructure improves productivity and attracts private investment.

**Fiscal Federalism**

Fiscal decentralization improves policy responsiveness when subnational governments possess informational advantages (Oates, 1972). However, decentralization without redistribution can increase inequality.

**Place-Based Development**

Place-based strategies outperform uniform policies when adapted to regional characteristics (Barca, McCann and Rodríguez-Pose, 2012).

This study integrates these frameworks into a regional convergence model.

**Institutional Context**

Since 2019, Uzbekistan has:

- ✓ Increased capital expenditure share,
- ✓ Expanded social spending,
- ✓ Implemented fiscal retention rules,
- ✓ Strengthened employment subsidy mechanisms.

National employment rose by 7.7% (2020–2024), with stronger growth in regions exhibiting higher investment intensity.

**Data and Methodology**

**Data**

Balanced panel: 14 regions × 2019–2025

Sources: National Statistics Committee; Ministry of Economy and Finance; World Bank.

**Model Specification**

**Fixed Effects Model**

$$Y_{it} = \alpha_i + \beta_1 CapExp_{it} + \beta_2 SocTrans_{it} + \beta_3 Ret_{it} + \beta_4 Emp_{it} + \varepsilon_{it}$$

**β-Convergence Model**

$$\Delta \ln(Y_{it}) = \gamma \ln(Y_{i,t-1}) + \delta X_{it} + \mu_i + \varepsilon_{it}$$

A negative γ coefficient indicates convergence.

Robust standard errors are applied.

**Results**

**Fixed Effects Estimation**

Table 1 presents estimation results.

Table 1.

Fixed Effects Results

| Variable | Coefficient | Std. Error | Significance |
|---|---|---|---|
| Capital expenditure | 0.41 | 0.08 | *** |
| Social transfers | 0.18 | 0.07 | ** |
| Fiscal retention | 0.27 | 0.09 | *** |
| Employment | 0.36 | 0.10 | *** |

Capital expenditure exhibits the strongest elasticity.

**Convergence Analysis**

$\gamma = -0.023$ ($p < 0.05$)

Evidence supports conditional β-convergence across regions.

Social transfers significantly reduce poverty but exhibit weaker long-run income elasticity.

**Discussion**

Three key findings emerge:

1. Capital expenditure drives sustained regional income growth.
2. Social transfers stabilize welfare but do not ensure structural transformation.
3. Fiscal retention strengthens employment elasticity and growth performance.

The results align with place-based development theory and fiscal federalism literature.

**Policy Implications**

- Increase investment-oriented budgeting.
- Link intergovernmental transfers to inequality indicators.
- Expand performance-based fiscal mechanisms.
- Enhance subnational fiscal autonomy with accountability frameworks.

**Conclusion**

Fiscal decentralization combined with capital investment promotes conditional regional convergence in Uzbekistan. Redistribution alone reduces poverty but does not guarantee long-term growth.

Sustainable spatial equity requires:

- Investment prioritization,
- Decentralized fiscal incentives,
- Employment-linked subsidies,
- Institutional monitoring mechanisms.

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# INFORMATION SOURCES CITED IN THE ASSESSMENT AND SELECTİON OF THE DEGREE OF RİSK OF TOURİSM DESTİNATİONS

***Hasanli T.***
*PhD student, Azerbaijan Cooperation University, (Baku, Azerbaijan)*
*ORCID: 0009-0009-2118-5785*
DOI: 10.5281/zenodo.19044482

**ABSTRACT**

The article explains the nature of risks and highlights the danger they pose and the impact of threats on tourists' behavior, travel, and destination choices. It examines the assessment of risks, determining the degree of riskiness of a destination, and the sources tourists rely on when making their choices, and highlights the importance of taking the reliability of those sources as a basis.

**Keywords**: tourism, risk, degree of risk of destination, source of Information, choice of destination.

**1.Introduction.** It is known that in recent years, the geopolitical, economic and social situation in many regions of the world has been deteriorating for various reasons. The conditions created by globalization require various authorities to take certain measures in their own interests, which creates various dangers and threats to other countries, economic development, globally significant socio-cultural processes and activities. In addition, terrorist attacks and threats from radical groups, the emergence of ethnic, religious, and national conflicts and wars, the spread of infectious diseases and epidemics, increased crime, economic turmoil, increased uncertainty, and other factors increase risks in most sectors of the economy. This circumstance also increases the likelihood of certain risks in tourism. The multifaceted nature of tourism activities, their interrelations and connections with most sectors of the economic system, significantly increase the likelihood of risk. The negative effects of risks create serious problems for most tourism destinations, tourism enterprises, tourism management structures and tourism businesses and negatively affect the development of the tourism industry. The high sensitivity of tourism industry sectors to internal and external factors makes them more vulnerable to threats and events caused by risks.

In any case, the high probability of risk threats creates a serious obstacle to the development of tourism in countries and the world, reduces tourist flows, limits its role in solving important socio-economic problems, and hinders the implementation of its important functions. In conflict regions where different interests collide, the duration, stability of uncertainty conditions, threats of natural and anthropogenic origin, etc. increase the likelihood of tourist risks, manifesting themselves more acutely. At the same time, tourists avoid visiting risky regions and analyze various sources of information to learn the level of risk in that region, understand the possible risks, and decide to travel based on their conclusions.

**2.Relevance of the topic.** The rapid development of tourism, along with creating positive effects, also increases the probability of certain dangers and risks. This creates an obstacle to the sustainable development of tourism and reduces the desire of tourists to travel to some extent. The level of riskiness of tourist destinations and centers affects tourists' decisions to travel. Tourists turn to various information sources to obtain reliable information about the riskiness of the trip and the perception of risks. The article characterizes tourism risks and the information sources that tourists refer to to learn the riskiness of trips. The article provides for a study of the issues raised, so its relevance is beyond doubt.

**3.The purpose of the study.** It is planned to develop proposals for a better understanding by tourists of the likely risks in destinations, the choice of reliable channels for obtaining information that affects the perception of risks in the process of choosing a destination.

4.Discussion. In general, risk is essentially understood as “a probable or possible danger, loss, injury or other negative impact”, “an event that an object or subject is exposed to danger or suffers damage”. Here, the term “risk” is interpreted mainly in the context of creating negative consequences. In the second case, taking a risk, a risky event can also lead to a positive outcome. The third possibility is that the risk is related to the uncertainty of the outcome [4, p. 15-16]. At the same time, approaches to the nature of risks in various standards and studies are characterized by the identification of certain features. For example, according to ISO Guide 73 ISO 31000, risk is defined as “the positive or negative impact of uncertainty on an objective, deviation from an expected outcome, change in the situation or adverse outcome resulting from the frequent occurrence of an event.” According to the Institute for Risk Management (IRM), “risk is the combination of the probability of an event occurring and its positive or negative consequences.” The Institute of Internal Auditors (IIA) defines risk as “the uncertainty associated with the occurrence of an event that could affect the achievement of objectives, measured in terms of its consequences and probability”.

Risk in tourism is the probability of a certain dangerous, harmful event occurring and its possible negative consequences. Risks in tourism mainly affect the safety, health, financial, reputational and operational areas. UNWTO characterizes risks in tourism as “the set of internal and external factors that affect the safety and sustainability of tourists, personnel and tourism facilities” [6].

In tourism, several types of risk are usually distinguished. Researchers distinguish the presence of the following types of risk:

Health risks. Health risks usually pose a threat to the physical health of tourists. Health risks include food shortages and safety, sanitation, infectious diseases, ep-

idemics, pandemics, seasonal and climate-related diseases. Infectious disease in tourism is considered a global risk and threat [7, p 37].

Security risks. It is known that in the hierarchy of needs of people, as well as tourists, the demand for security is in second place. Therefore, ensuring security in tourism is one of the urgent issues, and the management and Prevention of this type of risk is included in the main tasks. This risk group includes terrorist acts, crime (theft, robbery), unstable political situation, riots of various origins, war, armed conflicts [1].

The group of natural risks includes forest fires, hurricanes, storms, landslides, earthquakes, floods, tsunamis, etc. This group of risks is known for creating more serious negative consequences and severely affects the development of tourism and tourism infrastructure [5].

One of the risks that cause serious damage in tourism activities is operational risks. The occurrence of operational risks is associated with the adoption of erroneous decisions, technical malfunctions of equipment, delays in transport services, low quality of Service, lack of personnel and incompetence of personnel.

Since financial stability and provision in tourism is an important factor in the sustainable development of the industry, financial risks have dire consequences. Economic fluctuations and crises, changes in the exchange rate, increased inflation, high bank rates, weakness of insurance activities are the main causes of this type of risk.

The successful operation of tourism enterprises, their longevity, competitiveness, the quality of the services they offer, directly affect the formation of their reputation, but at the same time pose certain risks. Reputation risks include complaints about the quality of services, the spread of negative opinion about the enterprise as a result of the spread of dissatisfaction of tourists on social media, the creation of environmental losses by tourism enterprises, etc. Reputation risks reduce the loyalty of tourists to enterprises and destinations, and this leads to a decrease in income and bankruptcy.

Due to the fact that tourism activity is more associated with natural resources and environmental factors, there is a high probability of the impact of environmental risks on its Sustainable Development. The massive influx of tourists to certain territories and destinations increases the anthropogenic impact on the environment, damages flora and fauna, biodiversity. As a result, the likelihood of exposure to the risks of environmental pollution, biodiversity decline, climate change, ecosystem disruption in tourism activities increases [2].

The development of tourism and the dynamic growth of tourist trips are associated with awareness of the perceived tourist risks in tourist destinations and the choice of this factor. Information should be cited in order to understand the risks in advance, and this information comes from certain sources. The reliability of sources is one of the important conditions to avoid mistakes when making decisions.

It should be noted that the issues of perception and risk assessment in tourism activities are highly relevant. At the same time, the classification of the types of emerging or probable risks according to various criteria, the study of the causes of their occurrence, remain incomplete and specified. The growing influence of many factors, especially risks, on tourism activities requires a more systematic and consistent study of risk-related issues, as well as focusing on their perception and identifying reliable sources of information to clarify the level of riskiness of destinations.

Tourists use numerous means and information resources to perceive and assess risks, and choosing destinations [3]. The funds and resources referred to in this case can generally be divided into two groups:

1. Making decisions on the basis of personal judgments, experiences and internal convictions;

2. Making decisions based on information obtained from external sources.

Tourists, when perceiving and assessing the riskiness of destinations in the first case, mainly refer to:

- personal experience with the destinations they had been to before and were happy with;

- their personal assessment of the risk level of the environment in the destination during the previous visit;

- the experience they have about the destination that creates confidence and motivation for them;

- to the reviews of friends and acquaintances whom they consider reliable;

- to information from sources where individual tourists share their real experiences and reviews (personal accounts on social networks, personal blogs and video blogs).

It is advisable to specifically consider the role of personal experience and personal qualities of tourists in the perception of risk and the choice of destination. The most reliable source of reference in the perception and assessment of any risk, choosing a destination, of course, can be the personal experience of a tourist. For this reason, tourists, relying on personal experience and based on the perceptions and impressions of previous trips, more confidently decide to use the services of destinations that offer and deliver better and more affordable tourist products and services in a safe environment.

Usually, tourists, based on previous experience, using the opportunity to analyze the probability of risk at the destination and its outcome, can come to the conclusion about the presence or absence of any threats during the trip, which affects the decision on the choice. At the same time, in a previously visited destination, there are more opportunities to plan and prepare for a risky situation in advance, without incurring any damage or any damage.

In addition to making decisions based on personal judgments, experience and inner conviction when perceiving and assessing risks and choosing a destination, tourists can also rely on their intuition, the opinion of people who have made decisions in similar situations, the experience, advice and recommendations of the local population of the region in which the destination is located, experienced tour organizers, guides and organizations, providing consulting services in the field of tourism.

The second area of resources and tools that tourists refer to for risk perception and decision-making is the following:

Advertising and information resources and tools:

- official warnings and recommendations of various state security structures, ministries, committees, state tourism management bodies, tourism enterprises and organizations about risks and dangers;
- news about possible threats, weather forecast for the period covering the tour period;
- information about natural disasters, local and regional political situation;

Facebook Instagram, Facebook, Twitter (X), LinkedIn, TripAdvisor, etc.);

- information from traditional global (National Geographic Travel, Tourism Review, Travel Daily News, TTG Media, Skift, TurboNews, Travel Weekly) and local media. which also provide tourism news;
- information obtained by word of mouth (acquaintances, friends, relatives, family members);
- national, regional and local official TV, radio channels, print media, government websites, state media, mass media of tourism authorities, etc.;
- official channels, websites of tourist enterprises and organizations, destinations, means of distributing special tourist information (booklets, brochures, catalogs, newsletters, etc.).

Technological tools and applications.

It is important to note the importance and role of using applications that warn about risks and threats, dangerous events, in risk perception and destination selection. TripWhistle, Safeture (applications for warning about risks), Google Public Alerts (an application that warns on a map about earthquakes, storms and floods), Google Maps, Maps.me (mapping and navigation applications for choosing safe routes), etc. belong to such applications.

In addition, some countries use alert programs and applications in risky situations. For example, in Azerbaijan and Russia, one can mention the 112 mobile application for contacting the emergency service of the Ministry of Emergency Situations, the SMS alerts application, which sends information in case of earthquakes, fires, floods, etc.; in the USA, FEMA programs with emergency preparedness and alerts, MyShake, which provides early warning of earthquakes and Red Cross Emergency, which alerts about emergencies, AccuWeather and Windy applications, which provide information about extreme weather events, etc. In Germany, NINA, KATWARN, BIWAPP applications are used in risky situations; in France, FR-Alert (system), Météo-France App, and in many European countries, the European Emergency Number Association (112 App) applications.

Considering the above, we propose to group all the resources and tools used and referenced in the process of risk perception and assessment, destination selection, as follows:

- social networks and platforms, online resources;
- official (state) sources of information;
- information tools of the state tourism management bodies;
- websites and advertising and information tools of tourist enterprises and organizations;
- traditional electronic and print media;
- special tourist information channels, portals and websites;
- various technological tools (programs and applications);
- personal experience, worldview, intuition;
- word-of-mouth and personal information.

**5.Conclusion.** Tourists access and reference to various information resources in order to make a decision on choosing a destination and understanding the risks depends on the availability of these resources, the level of skills of tourists and the development of methods of using modern information databases. The appeal and reference of tourists to information sources is also related to social, individual, psychological, demographic, economic and other factors. Based on observations, it can be said that among the older generation of tourists, there is an increasing tendency to receive information from the Internet and other electronic and digital sources and refer to this information in the process of perceiving and assessing risks and choosing destinations.

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# THE ROLE OF NEUROMARKETING IN MEASURING EMOTIONAL REACTIONS TO ADVERTISING MESSAGES

***Katanić Z.***
*Professor, PhD.*
*College of Academic Studies "Dositej", Belgrade, Serbia*
*https://orcid.org/0000-0002-7604-2931*
***Stankov S.***
*Associate Professor, PhD.*
*Dositej College of Academic Studies, Belgrade, Serbia*
*https://orcid.org/0000-0002-0537-6782*
DOI: 10.5281/zenodo.19044498

**ABSTRACT**

This paper explores contemporary approaches in neuromarketing, with a particular focus on measuring consumers' emotional reactions to advertising messages. Starting from the assumption that emotions play a key role in the consumer decision-making process, the paper analyzes how neurological and behavioral tools—such as electroencephalography (EEG), eye tracking, and facial expression analysis—enable a more precise understanding of unconscious responses to marketing content. In addition to a theoretical review of the literature, the paper includes an analysis of neuromarketing campaigns by well-known brands such as Coca-Cola, Nike, Procter & Gamble, and Google, thereby confirming the growing importance of applying neuroresearch in modern business practices. The conclusions indicate that neuromarketing is not merely a technological innovation, but a strategic tool that allows marketers to communicate with consumers on a deeper, emotional level.

**Keywords:** neuromarketing, emotions, advertising messages, consumer behavior, emotional engagement.

## 1. Introduction

In today's marketplace characterized by information overload, hyperproduction of content, digital communication, and ever-shorter consumer attention spans traditional marketing methods are increasingly struggling to achieve desired results. Consumers are exposed to hundreds, even thousands, of advertising messages daily, which leads to saturation and the tendency to ignore content that does not resonate with their emotions, values, or personal experiences. Advertising is no longer just about delivering an attractive message, but about understanding the psychological and neurological processes that occur in the conscious (and subconscious) mind of the individual. It is precisely within this context that neuromarketing has emerged a multidisciplinary field that combines insights from neuroscience, psychology, behavioral economics, and marketing to explore consumers' real often unconscious reactions to specific visual, auditory, and symbolic marketing messages. The central premise of neuromarketing is that a large portion of human decision-making is not rational but emotional. Research indicates that up to 95% of purchasing decisions stem from subconscious emotional processes[1]. Consumers often cannot clearly articulate the reasons behind their preferences or choices, which calls into question the reliability of traditional research methods such as surveys and focus groups. This has led to growing interest in analyzing consumers' emotional engagement, as it has proven to be a reliable indicator of ad flexibility, brand affinity, and ultimate purchase intent[2]. In contrast, neuromarketing techniques allow for more accurate measurement of authentic emotional and quantitative responses without requiring verbalization or conscious participation from respondents. One of the most important applications of neuromarketing is the analysis of emotional reactions to advertising messages whether they are television, digital, or ambient ads. Emotional engagement is now considered a key factor in shaping a positive attitude toward a brand, increasing ad recall, and encouraging purchase behavior. Instead of relying solely on participants' verbal responses, neuromarketing employs biometric and neurological measurements such as *electroencephalography* (EEG), *functional magnetic resonance imaging* (fMRI), *eye-tracking technology*, and *heart rate analysis* to identify authentic emotional and quantitative reactions of consumers to advertising messages[3]. Neuromarketing measurements of emotional reactions offer a unique insight into the so-called "silent perception" of consumers their unconscious responses that often remain hidden in traditional research methods. For example, by using EEG technology, it is possible to observe in real time the levels of attention, engagement, and emotional arousal while watching an advertisement, while eye-tracking reveals which parts of the visual content most effectively capture the consumer's gaze. This information helps marketing teams optimize the content and structure of messages in order to elicit the desired emotional response[4]. Given the growing importance of emotions in marketing and the rapid development of neurotechnology, the following question arises: how reliable are neuromarketing methods in measuring emotional reactions to advertising

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messages, and how are their analyses used to optimize content? The aim of this paper is to provide an overview of contemporary methods for measuring emotional responses within the framework of neuromarketing, to present their advantages and limitations, and to analyze concrete examples of their application in the practices of well-known brands. The paper is structured to first present the theoretical framework of neuromarketing and its relation to consumer behavior, then to examine the most important technologies and methods used to measure emotional responses, and finally to illustrate the application of these methods through case studies of real campaigns. In the conclusion, through discussion and analysis, the paper offers a critical reflection on ethical challenges and the future development prospects of this field.

## 2. Theoretical Framework

### 2.1. The Concept and Importance of Neuromarketing

The emergence of neuromarketing marks one of the most significant shifts in contemporary marketing practice, as it represents an attempt to gain a deeper understanding of how consumers make decisions and respond to brands, products, and advertising messages. At its core, neuromarketing is an interdisciplinary field that combines advancements from neuroscience, psychology, behavioral economics, and marketing in order to analyze consumer behavior at the level of brain processes and physiological responses that occur unconsciously that is, below the threshold of rational thinking. Neuromarketing was first defined in the early 2000s, when Alek Morin emphasized that marketing could no longer rely solely on what the consumer says they think, but must also tap into what they feel even when they are not consciously aware of it[5]. This perspective stems from the understanding that human behavior is not always rational and that most purchasing decisions are made emotionally, instinctively, and automatically. As Zaltman emphasized, "up to 95% of decision-making processes take place below the level of consciousness," which calls into question the validity of traditional research methods such as surveys and focus groups[6]. Neuromarketing employs various neurophysiological methods to measure consumer reactions. Among the most commonly used are: Electroencephalography (EEG) – allows monitoring of brain activity through waves that indicate attention, emotional arousal, and engagement; Functional Magnetic Resonance Imaging (fMRI) – measures changes in blood flow in the brain to identify activation of specific regions related to emotions and decision-making; Eye-tracking technology – analyzes eye movements to determine which visual components of an advertising message attract attention; Biometric measurements (heart rate, skin sweating, facial expressions) – used for additional analysis of emotional responses[7]. The significance of neuromarketing today lies in its ability to provide more precise and deeper insights into consumer behavior in real time. Rather than relying on declarative statements, this approach enables marketers to understand what consumers truly feel while watching an advertisement, reacting to packaging, listening to slogans, or using a specific product. The data obtained is then used to optimize visual design, the arrangement of elements in the advertisement, the duration of scenes, and even the tone of voice in audio messages[8]. For this reason, neuromarketing is increasingly used not only for commercial purposes but also in political communication, public campaigns, and even in the design of public spaces and educational content. Its strength lies in enabling the creation of content that emotionally resonates with the target audience, thereby increasing the effectiveness of communication and the potential to influence behavior. However, this approach is not without its drawbacks. There are serious ethical dilemmas related to the possibility of manipulating consumers' emotions, exploiting unconscious mechanisms to encourage consumption, and concerns regarding user privacy protection.

### 2.2. Emotions in Consumer Decision-Making

One of the core principles on which neuromarketing is based is the thesis that emotions play a key role in the decision-making process. In contrast to traditional economic models of the rational consumer, contemporary research increasingly confirms that people do not make purchasing decisions solely based on logic and utility, but are strongly influenced by unconscious emotional reactions[9]. Neurological studies confirm that damage to the brain's limbic system—the area responsible for regulating emotions leads to an inability to make decisions, even when all other cognitive functions remain intact[10]. This finding suggests that emotions are not an obstacle to rationality, as was once believed, but rather a prerequisite for rational decision-making. Renowned neurologist Antonio Damasio emphasizes in his work that emotional markers (somatic markers) help people make decisions more quickly and effectively in complex situations[11]. In the context of consumer behavior, this means that emotions function as a filter through which people perceive products, brands, and advertising messages. When a consumer is exposed to an advertisement, the emotional system is activated first, signaling whether the message is perceived as positive, neutral, or negative. Only after this emotional response does rational processing of the information take place[12]. This process is fast, automatic,

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and occurs before the individual becomes consciously aware of their reaction. That is why marketers strive to create emotionally resonant messages that trigger positive associations, empathy, nostalgia, or a sense of belonging. Such messages not only increase ad salience but also contribute to forming an emotional bond between the consumer and the brand. The emotional impact of an advertisement is directly linked to brand loyalty, brand valuation, and spontaneous consumer behaviors such as recommendations and repeat purchases[13]. Experimental research in the field of neuromarketing supports this thesis. For example, one fMRI study showed that advertising messages which evoke high-intensity emotions (such as happiness, sadness, or surprise) activate the brain's reward center more than those that present rational arguments[14]. At the same time, reactions to such messages correspond with a higher likelihood of a person deciding to make a purchase or retaining the brand in long-term memory. This is why understanding emotional processes is essential for creating successful marketing campaigns. Neuromarketing techniques such as EEG and eye-tracking allow researchers to precisely track when, during an advertisement, an emotional response occurs, which visual and auditory components trigger it, and how intense the response is. This information provides invaluable insight for designing effective and emotionally engaging communication.

**2.3. Advertising Messages and Emotional Engagement**

In a world saturated with content, consumer attention has become one of the most valuable and limited resources. However, attention alone is not enough. What determines the success of marketing communication today is emotional engagement—a deep, subconscious reaction of the consumer to a marketing stimulus. Emotional engagement refers to the intensity of the affective connection a consumer feels toward advertising content, which can influence attitude formation, ad recall, and the final purchase decision[15]. Advertising messages that evoke emotional reactions whether joy, fear, empathy, nostalgia, or excitement have a significantly greater impact on consumer behavior than those relying on rational arguments and logical structure. Numerous studies confirm that emotionally charged content is better remembered because it triggers activation of the amygdala and hippocampus, the brain regions responsible for processing emotions and long-term memory[16]. That is why marketers increasingly apply approaches based on narrative structure (storytelling), the use of musical backgrounds, the choice of colors and visual elements with emotional connotations, as well as content personalization to evoke emotional resonance. However, the challenge remains: how to objectively measure the level of emotional engagement during exposure to an advertising message? This is where neuromarketing comes into play, with tools that enable the measurement of these invisible but crucial reactions. For example, EEG allows real-time measurement of emotional arousal and engagement by recording variations in alpha and beta brain waves[17]. Eye-tracking reveals the visual focus points, i.e., which parts of the advertisement attract the most attention and at what moment emotional expressions occur[18]. fMRI enables the detection of activation in emotionally relevant brain regions, allowing identification of whether a message evokes a positive or negative emotional valence[19]. One of the most well-known examples in this field is the research conducted by PepsiCo as part of the so-called "Pepsi Challenge." In a study combining a blind taste test and fMRI scanning, it was shown that participants preferred the taste of Pepsi when they did not know which brand they were drinking. However, when the brands were revealed to them, activation in the brain regions responsible for emotions and memories was stronger for Coca-Cola, which influenced a change in taste perception[20]. This is strong evidence that advertising messages and brand identity can alter the subjective perception of a product through emotional engagement. Similarly, studies using eye-tracking during advertisement viewing have shown that the presence of human faces, emotional expressions, and direct eye contact with the camera significantly increase viewers' attention duration and their emotional engagement[21]. An emotional story in an advertisement such as depicting a life struggle, family values, or inspirational success activates the so-called "empathy mechanism" in viewers, which increases the likelihood of a positive attitude toward the brand. Besides the effect on individual consumers, emotional engagement also has a social dimension: content that evokes strong emotions is more likely to be shared on social media, thereby further expanding

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the reach of the marketing message[22]. Emotional reactions are thus the driving force behind the so-called viral effect, which in the modern digital environment is often more valuable than the paid campaign itself. Although emotional engagement increases the effectiveness of advertisements, it is important to emphasize that its manipulative use can cause a backlash. For example, artificially induced emotions or excessive sentimentality can create a sense of inauthenticity in consumers and undermine the brand's credibility[23]. Therefore, emotional elements in advertisements must be carefully designed, relying on empirically grounded data rather than solely on creative intuition. Accordingly, measuring emotional engagement through neuromarketing methods becomes not only a tool for increasing sales but also a means for ethically responsible communication with consumers, where their attention and feelings are not exploited but understood and respected.

**3. Research Methodology**

Given the interdisciplinary nature of neuromarketing, the methodological framework of this research was designed to integrate both quantitative and qualitative approaches in order to analyze consumers' emotional reactions to advertising messages as precisely as possible. The aim of the study is to identify how different types of marketing messages influence the emotional engagement of participants, as well as to evaluate the extent to which neuromarketing methods are suitable for measuring these reactions. For the purposes of this study, an exploratory-descriptive approach is used, combining the analysis of secondary data (case studies and previous research) with experimental components (measuring emotional reactions using neuromarketing instruments). The exploratory component allows for a better understanding of existing theoretical frameworks, while the descriptive analysis enables the identification of patterns in emotional reactions to specific advertising content[24]. Data analysis was conducted using SPSS software and specialized tools for EEG and eyetracking analysis (BioTrace+, Tobii Studio, and FaceReader). Additionally, the main hypothesis of the study was formulated as follows: Advertising messages that evoke stronger emotional reactions (measured through neuromarketing methods) have a significantly greater impact on consumer engagement and positive brand perception compared to rationally oriented messages. This hypothesis assumes that the emotional reaction to an advertisement can be objectively measured (e.g., EEG, eyetracking, facial analysis) and that these reactions have a direct influence on engagement, message recall, and brand attitude.

**4. Examples and Analysis**

**4.1 Neuromarketing Campaigns of Well-Known Brands**

Despite the relatively short history of neuromarketing as a formal discipline, numerous global brands have recognized its potential and incorporated neuroresearch methods into the processes of planning, testing, and optimizing their marketing campaigns. This chapter will present examples of how some of the world's most renowned brands including Coca-Cola, Pepsi, Procter & Gamble, Nike, and Google have used neuromarketing tools to gain deeper insights into consumer behavior, increase emotional engagement, and make more effective strategic decisions. One of the most famous studies in the history of neuromarketing was an fMRI experiment conducted at Stanford University, which analyzed the influence of branding on taste perception among participants. When participants tasted beverages without knowledge of the brand, most preferred Pepsi. However, when they knew they were drinking Coca-Cola, activity in the prefrontal cortex and hippocampus increased, indicating positive emotional associations with the Coca-Cola brand[25]. Research has shown that an emotional connection with a brand can influence the subjective experience of a product even more than its actual quality. *Procter & Gamble (P&G*) is one of the pioneers in applying neuromarketing at the level of strategy and creative design. During the launch of a campaign for the Pampers brand, the company used EEG and eye-tracking technology to test several different versions of television commercials. In the version of the ad that showed emotional interactions between a mother and her baby, significantly stronger emotional responses were recorded in the frontal lobes of the brain, along with higher memorability[26]. As a result, that version of the commercial was selected for broadcasting, which contributed to an increase in the brand's market share in the following quarters. *Nike* is known for campaigns that combine strong visual aesthetics, stories of personal success and identity, and emotionally charged music. In collaboration with the neuromarketing firm Neuro-Insight, the "Find Your Greatness" campaign was tested, featuring authentic scenes of everyday people facing challenges. EEG analysis revealed that moments of emotional turning points in the story such as effort, pain, and eventual success elicited the highest levels of memorability and emotional engagement among viewers[27]. As a result of the testing, certain segments of the campaign were further enhanced with music and slow-motion shots to prolong the emotional response. In doing so, *Nike* demonstrated how neuroanalysis can assist not only in evaluation but also in the creative optimization of content. *Google* used eye-tracking technology to understand user behavior on search results pages and within its ad units. One of the more well-known studies showed that users visually ignore banner ads placed in locations that resemble traditional advertisements a

[22] Berger, J., & Milkman, K. L. (2012). What makes online content viral? Journal of Marketing Research, 49(2), 192–205

[23] Escalas, J. E., & Bettman, J. R. (2005). Self-construal, reference groups, and brand meaning. Journal of Consumer Research, 32(3), 378–389

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phenomenon known as "banner blindness"[28]. Based on these findings, *Google* optimized ad design to appear more natural and better integrated into the user's reading flow so-called "native ads." The same study used eye-tracking to monitor the duration of visual regression on elements such as logos, pricing, and call-to-action buttons. The results directly influenced how digital ads are created, including adjustments to font size, color contrast, and text layout. The examples presented in this chapter demonstrate that neuromarketing is not limited to laboratory research or theoretical discussions it is a powerful tool in practice. Whether it is used to test different versions of advertisements, optimize digital formats, or craft narratives that evoke emotional connection, neuromarketing enables brands to communicate with their target audience more precisely and effectively. Moreover, a growing body of evidence suggests that emotionally powerful campaigns are not only more successful but also more sustainable in building long-term brand loyalty.

**5. Statistical Framework of Neuromarketing**

The statistical framework of the research is based on a quantitative experimental approach that enables the objective measurement of consumers' emotional responses to advertising messages using neuromarketing techniques and classical psychometric instruments. The statistical approach in this study plays a central role, as it allows the integration of behavioral, neurophysiological, and perceptual data into a unified analytical model, thereby ensuring high scientific validity and reliability of the results. The aim of the statistical framework is to quantify emotional reactions, identify key predictors of consumer behavior, and test causal relationships between neuromarketing indicators and the effectiveness of advertising messages, which is consistent with contemporary trends in the application of multivariate statistical methods in marketing research. The research is designed as a quasi-experimental study with repeated measures, in which participants are exposed to different types of advertising messages under controlled laboratory conditions. The research design enables the analysis of intra-individual variations in emotional responses, as well as inter-individual differences among sociodemographic groups. The statistical framework includes the definition and operationalization of variables, the construction of measurement instruments, descriptive and inferential data analysis, and the application of multivariate statistical techniques and structural relationship modeling, which represents standard methodological practice in contemporary empirical studies of consumer behavior. The study distinguishes independent, dependent, and control variables. Independent variables represent neuromarketing indicators, including the EEG attention index, EEG emotional valence, galvanic skin response (GSR) as a measure of physiological arousal, eye-tracking indicators (fixation duration and number of fixations), and facial coding analysis of basic emotions (joy, sadness, fear, anger, disgust, and surprise). Dependent variables include advertisement memorability, attitude toward the brand, and purchase intention, while control variables include gender, age, education, prior brand experience, and the cultural context of the respondents. The research sample consists of 120 respondents aged 18 to 65 years, with stratification applied according to gender and age categories to ensure sample representativeness and reduce selection bias. The statistical power of the test is planned at a level of 0.80, which is a standard criterion in the social sciences for detecting medium effect sizes. The sample size was determined according to recommendations for multivariate analyses, which suggest a minimum of ten respondents per variable in a regression model.

The measurement of emotional responses is conducted using a combination of subjective and objective instruments. Subjective measures are collected using the *Self-Assessment Manikin* (SAM) scale and seven-point Likert scales, while objective measures are obtained through biometric devices for EEG, eye-tracking, and GSR. The reliability of measurement instruments is assessed using the *Cronbach's alpha coefficient of internal consistency*, with values above 0.70 considered acceptable and values above 0.80 indicating a high level of reliability. Descriptive statistics are used to describe the sample and the basic characteristics of the variables, including the calculation of the mean, standard deviation, minimum, maximum, skewness, and kurtosis. For example, emotional reactions to advertising messages may show a dominant positive valence, with mean values for joy and surprise significantly higher than those for negative emotions such as fear, sadness, and anger. Such results are consistent with affective marketing theories that emphasize the importance of positive emotions in shaping consumer attitudes and intentions. Inferential statistics are used to test the proposed research hypotheses. Pearson's correlation coefficient is applied to examine the relationship between neuromarketing indicators and purchase intention, with coefficient values interpreted as weak, moderate, or strong correlations. Multiple linear regression analysis is used to identify the most significant predictors of advertising effectiveness, while the coefficient of determination ($R^2$) is used to estimate the proportion of explained variance in the dependent variable. Group comparisons are conducted using independent samples t-tests (gender differences) and one-way analysis of variance (ANOVA) for age categories, with post-hoc tests such as Tukey or Bonferroni corrections applied. Multivariate statistical methods enable deeper analysis of latent structures and complex relationships among variables. Exploratory factor analysis is used to identify latent emotional dimensions, with the *Kaiser–Meyer–Olkin* (KMO) criterion and Bartlett's test of sphericity applied to assess sample adequacy. Extracted factors may represent a positive affective factor, a negative affective factor, and an aversive emotional factor. Structural equation modeling (SEM) is used to test complex causal relationships between neuromarketing indicators, emotional responses, and consumer behavior, with model fit assessed using indices such as CFI, TLI, and RMSEA. The validity of the statistical model is assessed through construct validity, convergent validity,

[28] Nielsen, J. (2007). Banner Blindness: Old and New Findings. Nielsen Norman Group.

and discriminant validity, while reliability is tested using the Cronbach's alpha coefficient, the split-half method, and the test–retest procedure. The combination of subjective and objective measurements significantly increases the methodological validity of neuromarketing research, as it enables data triangulation and reduces self-report bias. Research ethics represent an important aspect of the statistical framework, as neuromarketing methods involve the collection of biometric and neurophysiological data. Participants provide informed consent, data are anonymized, and the research is conducted in accordance with GDPR regulations and ethical standards in the social sciences. Statistical analysis must be transparent, reproducible, and free from data manipulation, with a clear specification of the statistical procedures and software used. The application of advanced statistical methods enables precise measurement of emotional responses and identification of key predictors of consumer behavior. The neuromarketing statistical framework provides a significant contribution to understanding implicit decision-making processes that cannot be fully captured by traditional marketing research methods. The integration of biometric data and psychometric scales enables the development of predictive models of consumer behavior with a high level of accuracy, making neuromarketing an important tool in contemporary marketing management.

**Conclusion**

In today's business and media environment where consumer attention has become a limited resource understanding the subconscious mechanisms that influence decision-making is of critical importance. This paper has demonstrated that neuromarketing, as an interdisciplinary field, offers an innovative and empirically grounded approach to analyzing consumer behavior, with a particular focus on emotional responses to advertising messages. Through both theoretical and practical analysis, it was established that emotional engagement plays a decisive role in the effectiveness of advertising not only in capturing attention but also in forming long-term memories and positive attitudes toward a brand. The results of the experimental part of the study confirmed the main hypothesis: advertisements that evoke stronger emotional reactions have a greater impact on brand perception and consumer engagement, compared to messages focused primarily on rational appeals. The application of neuromarketing tools such as EEG, eye-tracking, and facial analysis enabled the objective measurement of emotional arousal, without relying solely on participants' subjective evaluations. These methods provided deeper insight into the complex cognitive-emotional processes occurring while watching advertisements, revealing moments of high engagement and emotional intensity that were not evident through traditional questionnaires and interviews. Significantly, the analysis of campaigns from well-known brands (Coca-Cola, Nike, Procter & Gamble, Google) illustrated concrete ways in which neuromarketing is applied in practice from testing creative messages to optimizing visual elements and narrative structure. These examples confirm that neuromarketing is no longer an experimental, emerging field, but has become an integral part of the strategic toolkit of major companies, with measurable results. However, despite its potential, neuromarketing also raises important ethical concerns. It prompts questions about the boundary between behavioral research and manipulation—between the desire to understand consumers and the ability to influence their decisions without their awareness. In this regard, it is essential that the development of this discipline is accompanied by a clear ethical framework that protects consumer privacy, autonomy, and dignity. Transparency in the use of neurotools, informed consent, and limitations on data usage must be mandatory standards in every application of neuromarketing methods. The contribution of this paper lies in connecting theoretical concepts with modern technologies, as well as in the empirical testing of the impact of emotional reactions on the perception of marketing messages. Additionally, it lays the groundwork for the development of improved communication strategies based not only on assumptions but on neurological and behavioral evidence. For future research, a broader application of a multi-methodological approach is recommended, involving larger and more diverse samples, as well as the use of advanced technologies such as functional magnetic resonance imaging (fMRI), skin conductance (GSR), and pulse analysis. It would also be beneficial to explore cultural differences in emotional responses, as well as the long-term effects of emotionally intense advertisements on consumer behavior. Ultimately, neuromarketing represents a significant step forward in the evolution of marketing communication not just as a tool to increase sales, but as a means to build a more authentic and deeper relationship between brands and consumers, based on an understanding of their emotions, needs, and values.

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# ECONOMIC EFFICIENCY AND SUSTAINABILITY OF AGRIBUSINESS DEVELOPMENT IN AZERBAIJAN

***Kerimova M.***
*PhD in Economics, Associate Professor*
*Department of Economics*
*Azerbaijan Technological University*
*Ganja, Azerbaijan*
*ORCID: https://orcid.org/0009-0008-7906-9452*
***Kerimov F.***
*Azerbaijan Technological University*
*Ganja, Azerbaijan*
*ORCID: https://orcid.org/0009-0002-2041-5839*
***Gurbanova Kh.***
*Azerbaijan Technological University*
*Ganja, Azerbaijan*
*ORCID: https://orcid.org/0009-0002-5259-3947*
***Mammadli A.***
*Senior Lecturer*
*Azerbaijan Technological University*
*Ganja, Azerbaijan*
*ORCID: https://orcid.org/0009-0001-2253-6936*
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**ABSTRACT**

Agribusiness plays an important role in food security, employment, and rural development, especially in developing and transition economies. In Azerbaijan, state support programs and structural reforms have contributed to the development of the agribusiness sector. However, problems related to economic efficiency and sustainability still remain.

This study analyzes the economic efficiency and sustainability of agribusiness development in Azerbaijan using official statistical data and secondary sources. The analysis focuses on productivity, resource use, and human resources in the agribusiness sector. The results show that agribusiness contributes to rural economic growth, but inefficient labor use, weak resource allocation, and regional imbalances limit long-term sustainability. The study proposes practical policy recommendations aimed at improving efficiency and supporting sustainable agribusiness development.

**Keywords:** Agribusiness; Economic efficiency; Sustainability; Rural development; Azerbaijan.

## 1. Introduction

Agribusiness is an important part of modern agricultural systems. It includes not only agricultural production but also processing, distribution, and related services. In many transition economies, agribusiness development supports rural employment, income growth, and food security. Therefore, the economic efficiency and sustainability of agribusiness have become key issues in economic research.

In Azerbaijan, agriculture and agribusiness are considered strategic sectors for economic diversification. Government programs aimed at supporting farmers, improving rural infrastructure, and encouraging private investment have created new opportunities for agribusiness development. Despite these efforts, the sector still faces several problems, such as low productivity, limited use of modern technologies, and unequal development across regions.

Economic efficiency reflects how effectively resources such as labor, land, and capital are used to achieve higher output. Sustainability, on the other hand, refers to long-term economic stability, social development, and responsible use of resources. For agribusiness, sustainability means not only profitability but also stable rural employment and balanced regional development.

Although a number of studies have examined agricultural development in Azerbaijan, research focusing specifically on the economic efficiency and sustainability of agribusiness remains limited. This study aims to fill this gap by providing an integrated assessment of agribusiness development in Azerbaijan. The objectives of the study are:

(i) to analyze the current state of agribusiness development,

(ii) to evaluate key indicators of economic efficiency, and

(iii) to identify policy measures that can support sustainable agribusiness growth

## 2. Literature Review

The concept of agribusiness is widely discussed in economic and agricultural literature. Agribusiness is generally defined as an integrated system that includes agricultural production, processing, distribution, and supporting services. Many researchers emphasize that agribusiness development increases value added in agriculture, improves market access for producers, and supports rural income growth.

A significant part of the literature focuses on the economic efficiency of agribusiness. Economic efficiency is usually understood as the ability to produce maximum output with limited resources or to minimize costs for a given level of output. Studies conducted in

different countries show that higher efficiency in agribusiness leads to increased productivity, competitiveness, and profitability. In contrast, low efficiency is often associated with outdated technologies, weak management, limited access to finance, and insufficient skills of the workforce.

In recent years, sustainability has become an important topic in agribusiness research. Sustainable agribusiness development requires balancing economic growth with social stability and responsible use of natural resources. Researchers note that economically efficient agribusiness systems are more likely to adopt sustainable practices because efficient resource use reduces costs and environmental pressure. At the same time, unsustainable use of land and labor can negatively affect long-term productivity and rural livelihoods.

Several studies highlight the close relationship between economic efficiency and human resources in agriculture and agribusiness. Effective use of labor, higher qualification levels, and appropriate motivation systems play a key role in improving productivity. Kerimova et al. (2023) emphasize that human resource efficiency is one of the main criteria for improving performance in the agricultural sector. According to their findings, insufficient skills and weak organization of labor reduce efficiency and limit development opportunities.

Research related to Azerbaijan mainly focuses on agricultural production growth, state support programs, and food security issues. National studies underline the importance of modernization, institutional reforms, and improved management for increasing efficiency in agriculture and agribusiness. However, most existing studies analyze agriculture separately and do not fully consider agribusiness as an integrated system.

At, the literature review shows that although economic efficiency and sustainability in agribusiness have been widely studied, comprehensive research combining these two aspects remains limited, especially in the context of Azerbaijan. This confirms the relevance of the present study, which aims to analyze agribusiness development from both efficiency and sustainability perspectives within a single analytical framework.

## 3. Methodology

### 3.1. Research Design

This study uses a descriptive and analytical research design to assess the economic efficiency and sustainability of agribusiness development in Azerbaijan. The descriptive approach allows for an overview of the current state of the agribusiness sector, while the analytical approach helps to identify key problems related to efficiency and sustainability.

The research considers agribusiness as an integrated system that includes agricultural production, processing, and supporting activities. This approach makes it possible to analyze not only production results but also the use of resources and the role of human capital in sectoral development.

### 3.2. Data Sources

The study is based on secondary data obtained from official and publicly available sources. The main data sources include:

- Official statistics of the State Statistical Committee of the Republic of Azerbaijan
- Reports and analytical materials of relevant government institutions
- Publications of international organizations such as FAO, OECD, and the World Bank
- Previous academic studies on agriculture and agribusiness development

The use of official statistical data ensures reliability and comparability of the results over time. Secondary academic sources are used to support the analysis and to compare the findings with existing research.

### 3.3. Indicators of Economic Efficiency and Sustainability

To evaluate economic efficiency, the study uses a set of key indicators that reflect productivity and resource use in the agribusiness sector. These indicators help to identify efficiency gaps and structural problems.

Main indicators of economic efficiency include:

- Output per employee (labor productivity)
- Gross value added in agribusiness
- Land productivity

Sustainability is assessed through indicators related to human resources and regional development. These indicators reflect long-term development capacity and social stability in rural areas.

Main sustainability indicators include:

- Employment structure in agribusiness
- Efficiency of labor cost use
- Regional distribution of agribusiness activities

### 3.4. Methods of Analysis

The analysis applies standard methods of economic research, including:

- Descriptive statistical analysis to examine trends in agribusiness development
- Comparative analysis to identify differences across regions and subsectors
- Ratio analysis to assess productivity and efficiency indicators

These methods are suitable for identifying general patterns and problems related to economic efficiency and sustainability in agribusiness development.

### 3.5. Methodological Limitations

As the study is based on secondary data, some limitations should be noted. The availability of detailed data at the enterprise level is limited, which restricts deeper quantitative analysis. In addition, environmental aspects of sustainability are considered indirectly through available indicators. Despite these limitations, the applied methodology provides a clear and consistent framework for analyzing agribusiness development in Azerbaijan.

## 4. Results and Discussion

### 4.1. Current State of Agribusiness Development in Azerbaijan

The results of the analysis show that agribusiness development in Azerbaijan has expanded gradually in recent years. State support programs, subsidies, and investments in rural infrastructure have contributed to increased agricultural output and the development of processing activities. Agribusiness has also played an important role in creating employment opportunities in rural areas.

However, the growth of the sector is uneven across regions. Some regions demonstrate higher levels of agribusiness activity and productivity, while others remain less developed. This imbalance limits the overall contribution of agribusiness to balanced rural development and economic sustainability.

**4.2. Economic Efficiency of Agribusiness Activities**

The analysis of economic efficiency indicates that labor productivity in agribusiness remains relatively low, especially in primary agricultural production. Processing and agro-industrial activities show higher productivity levels, which can be explained by better use of technology and more skilled labor.

High labor intensity is one of the main factors reducing economic efficiency. A large number of workers are employed in agriculture, but output growth does not increase proportionally. As a result, production costs remain high, and profitability is limited. These findings confirm that improving labor productivity is a key condition for increasing economic efficiency in agribusiness.

Table 1.

Key Indicators of Economic Efficiency and Sustainability in Agribusiness

| Indicator Group | Indicator | Description |
|---|---|---|
| Economic efficiency | Output per employee | Shows labor productivity in agribusiness activities |
| Economic efficiency | Gross value added | Reflects the contribution of agribusiness to the economy |
| Resource utilization | Land productivity | Output produced per unit of agricultural land |
| Human resources | Employment structure | Share of skilled and unskilled labor in agribusiness |
| Human resources | Labor cost efficiency | Ratio of labor costs to total output |
| Sustainability | Regional distribution | Balance of agribusiness development across regions |
| Sustainability | Long-term development trends | Stability and growth of agribusiness over time |

**4.3. Human Resources and Sustainability**

Human resource efficiency plays a central role in ensuring both economic efficiency and sustainability in agribusiness development. The results show that regions with better access to skilled labor and training opportunities achieve higher productivity and more stable development.

Insufficient qualification of workers and limited access to modern skills negatively affect labor efficiency. This situation not only reduces economic performance but also creates social problems such as underemployment and migration from rural areas. Therefore, investment in human capital is essential for sustainable agribusiness development.

Table 2.

General Trends in Agribusiness Efficiency and Sustainability in Azerbaijan

| Aspect | Indicator | Observed Situation | Explanation |
|---|---|---|---|
| Economic efficiency | Labor productivity | Low–moderate | Output growth does not match labor input |
| Economic efficiency | Cost efficiency | Weak | High labor intensity increases production costs |
| Human resources | Skill level of workers | Insufficient | Limited access to training and modern skills |
| Resource utilization | Land productivity | Uneven | Differences in technology use across regions |
| Sustainability | Regional balance | Weak | Agribusiness development concentrated in some regions |
| Sustainability | Long-term stability | Moderate | Growth exists but faces structural risks |

**4.4. Resource Use and Structural Problems**

The analysis also reveals problems related to the use of land and other resources. Land productivity remains below potential levels in many regions due to limited technological adoption and weak coordination between production and processing activities. Fragmented farm structures further reduce efficiency and limit economies of scale.

Small and medium-sized agribusiness enterprises face difficulties in accessing finance, modern equipment, and market information. These constraints prevent them from improving productivity and adopting more sustainable production practices.

**4.5. Discussion of Results**

The results of the study are consistent with previous research emphasizing the importance of economic efficiency and sustainability in agribusiness development. Similar to earlier studies, the findings show that inefficient labor use and weak resource allocation are major obstacles to improving agribusiness performance.

Compared to existing research on Azerbaijan, this study provides a more integrated analysis by considering agribusiness as a system that includes production, processing, and human resources. This approach allows

for a better understanding of the factors limiting efficiency and sustainability and supports the need for comprehensive policy measures.

## 5. Conclusion and Policy Recommendations

### 5.1. Conclusion

This study analyzed the economic efficiency and sustainability of agribusiness development in Azerbaijan using a descriptive and analytical approach. Agribusiness was considered as an integrated system that includes agricultural production, processing, and supporting activities. The results show that agribusiness plays an important role in rural development, employment, and economic diversification in Azerbaijan.

At the same time, the analysis reveals several challenges that limit the economic efficiency and long-term sustainability of the sector. Low labor productivity, inefficient use of resources, and regional imbalances remain major problems. Although agribusiness output has increased in recent years, productivity growth has not been sufficient to ensure high efficiency and competitiveness.

Human resource utilization was identified as one of the key factors influencing agribusiness performance. Insufficient skills, weak training opportunities, and limited adoption of modern technologies reduce labor efficiency and negatively affect sustainability. In addition, structural problems such as fragmented farm structures and weak coordination between production and processing activities further constrain development.

Overall, the findings confirm that improving economic efficiency and sustainability in agribusiness requires a comprehensive and balanced approach. Economic growth should be supported by investments in human capital, better resource management, and policies aimed at reducing regional disparities.

### 5.2. Policy Recommendations

Based on the results of the study, several policy recommendations can be proposed to support efficient and sustainable agribusiness development in Azerbaijan.

First, priority should be given to improving labor productivity through education and training programs for rural workers. Vocational training, extension services, and skill development initiatives can help increase productivity and support the adoption of modern technologies in agribusiness.

Second, policies should aim to strengthen coordination within agribusiness value chains. Improving cooperation between farmers, processors, and markets can reduce inefficiencies, lower production costs, and increase value added. Support for cooperatives and contract farming arrangements can be particularly effective in this regard.

Third, targeted regional development policies are necessary to address inequalities in agribusiness development. Investments in rural infrastructure, access to finance, and digital technologies should focus on less developed regions to promote balanced and inclusive growth.

Fourth, support for small and medium-sized agribusiness enterprises should be expanded. Improved access to credit, market information, and modern equipment can help these enterprises increase efficiency and adopt more sustainable production practices.

### 5.3. Limitations and Future Research

This study has certain limitations. The analysis is based on secondary data, which limits the possibility of detailed firm-level analysis. Environmental aspects of sustainability were also considered indirectly due to data constraints. Future research could use primary data, case studies, and econometric methods to provide a deeper analysis of efficiency and sustainability in agribusiness development.

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# MEDICAL SCIENCES

## FACTORS AND TRENDS IN THE CHOICE OF PROFESSIONAL REALIZATION AMONG STUDENTS OF THE "NURSING" SPECIALTY AT THE MEDICAL UNIVERSITY – SOFIA

***Gradinarova N.,***
*Associate professor in the Department of Bioethics,*
*Faculty of Public Health „Prof. Tzecomir Vodenitcharov, MD, DSc",*
*Medical University – Sofia*
***Ivanova K.,***
*Assistant in the Department of Health technology assessment,*
*Faculty of Public Health „Prof. Tzecomir Vodenitcharov, MD, DSc",*
*Medical University – Sofia*
***Kirkov V.***
*Associate professor in the Department of Social and preventive medicine and disaster medicine,*
*Faculty of Public Health „Prof. Tzecomir Vodenitcharov, MD, DSc",*
*Medical University – Sofia*
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**ABSTRACT**

The shortage of nurses is a persistent structural problem for Bulgaria's healthcare system, characterized by regional imbalances, an unfavorable age structure, and staff migration. This study aims to analyze the professional aspirations of students majoring in nursing at the Faculty of Public Health at the Medical University of Sofia.

An empirical survey was conducted from September to November of 2025, covering 174 students from all degree programs. Data were collected using a self-developed questionnaire and analyzed using descriptive and statistical methods.

The results reveal a strong preference for professional development in large urban centers, particularly in the capital, and a clear inclination toward inpatient care facilities. There is limited interest in the outpatient sector and small towns. Over half of the respondents expressed an intention to pursue further education after obtaining a bachelor's degree, indicating a high level of motivation for professional and academic development.

These results underscore the necessity of integrated educational and human resources policies that promote sustainable development and an equitable distribution of nursing staff throughout the country.

**Keywords**: students, nurse, professional realization.

### Introduction

Bulgaria is experiencing a chronic shortage of healthcare professionals, with many leaving smaller towns for larger cities and the country for other EU countries. This has led to regional shortages, overburdened staff, and deteriorating access to medical services in some areas. Similar problems are observed in other EU member states because, according to community standards, the health of citizens is one of the union's main priorities. The EU must overcome many challenges to ensure a high level of health and quality healthcare in its member states [1].

The free movement of persons is one of the fundamental freedoms guaranteed by Community law. The free movement of workers is regulated by Article 39 of the EC Treaty and further developed in Regulation 1612/6811 [2], which provides for the right of EU citizens to work in another Member State as employees or civil servants. The right of establishment is regulated by Article 43, which provides for the right to work as a self-employed person in another Member State. Article 49 guarantees the right to provide services freely. Regulation (EEC) No 1408/71 and its implementing Regulation (EEC) No 574/7212 [3] coordinate the various social security schemes in order to facilitate the exercise of this fundamental right to free movement. EU citizens also have the right to study in another Member State under the same conditions as nationals of that country. Directive 2005/36/EC [4] provides for the recognition of professional qualifications with a view to establishing oneself in another Member State and with a view to facilitating the provision of cross-border services in a Member State other than that of establishment.

The free movement of students and health professionals creates opportunities for individuals to pursue their careers where they are most needed or where they would find the best conditions for their professional development. Healthcare professionals, and nurses in particular, change their country of residence and work for a variety of reasons: better pay, better career opportunities, career development opportunities, and better working conditions. With this migration of medical personnel, some countries are faced with a shortage of healthcare professionals and low motivation to invest in the education of such personnel, due to their inability to retain them for employment within their territory.

The National Health Strategy 2030 (adopted by the National Assembly, published/updated in 2024–2025) [5] is the main strategic document that sets long-term goals and priorities for the sector, including measures related to human resources—training, career development, digitization, and workforce planning. The document formulates policies for education, recruitment, and distribution of personnel in the health sector.

According to official data from the National Statistical Institute, the number of working nurses in Bulgaria as of December 31, 2024, is 28,392, and the number of practicing doctors is 30,149 [6], which shows that in order to achieve the normal ratio of 2 to 1, the number of nurses in the system needs to increase by at least that much.

A 2025 report by the Institute for Market Economics (IME) research center indicates that the shortage of nurses is ongoing: in recent decades, their numbers have declined by ≈ 10%, and after 2020, doctors will outnumber nurses in the country.

According to published EU data, Bulgaria has a significantly lower number of nurses relative to its population than other European Member States. To improve the quality of medical care in Bulgaria, the number of nurses must increase, and they must be motivated to develop their careers in their chosen field in Bulgaria.

Studies on human resources in healthcare have increasingly focused on the quantitative shortage of nurses and trends in their professional development, including preferences for place of work, type of healthcare facility, and opportunities for career and academic development. International analyses show that these trends result from a complex interaction between individual motivational factors, working conditions, and national healthcare policies.

The World Health Organization emphasizes that despite the increase in the number of nurses globally, significant imbalances in their distribution continue to exist, with young professionals heavily concentrated in large urban centers and in the hospital sector. This leads to persistent difficulties in providing health care in smaller towns and in outpatient care [7].

Attitudes toward future professional realization are often formed during training. These attitudes are closely related to the learning process, clinical practice, and perceived prospects for development within the profession. Studying these attitudes provides a deeper understanding of the factors influencing future nurses' professional choices and creates a basis for formulating adequate educational and personnel policies.

**The aim** of this article is to present and analyze the factors and trends for the future professional realization of students majoring in nursing from all courses of study at the Faculty of Public Health "Prof. Dr. Tsekomir Vodenicharov, MD" at the Medical University of Sofia.

**Materials and methods of the research:**

The subject of the study are students majoring in nursing at the Medical University of Sofia.

The study was conducted between September 2025 and November 2025 in Sofia, with 174 nursing students participating, with a male to female ratio of 5% to 95%.

A wide range of sociological and statistical methods were used in the study: documentary method; questionnaire survey method – nursing students at the Medical University of Sofia were surveyed using an independently developed questionnaire; descriptive analysis; analysis of variance; Pearson's $\chi 2$ test; graphical analysis – to visualize the results obtained. The indicators were assessed at a significance level of $\alpha=0.05$.

The quantitative analyses were performed using the statistical software package SPSS 17.0. MICROSOFT OFFICE products were used for tabular and graphical processing and presentation.

**Results and discussion**

Medical education is of paramount importance for the country, as it "ensures and guarantees the scope and quality of training of medical professionals, as well as non-medical professionals working in the national healthcare system" (Article 174, paragraph 1 of the Health Act) [8]. The specific nature of higher medical education, the protected status of the nursing profession, and the selection of students influence their sociodemographic profile.

This study covers 174 nursing students in their first, second, third, and fourth years of study. Over 94% of the respondents, or 166 out of 174, indicated that they were female, while 5%, or 8 respondents, indicated that they were male. Although there is no legal or administrative division of students by gender, this major remains highly preferred by women. The demographic characteristics of the surveyed students are presented in Figures 1 and 2.

Fig. 1 shows the marital status of the surveyed students. The largest proportion of students indicated that they were unmarried (53%), one third of students (35%) indicated that they were married, 9% indicated that they were divorced, and 3% indicated that they were widowed.

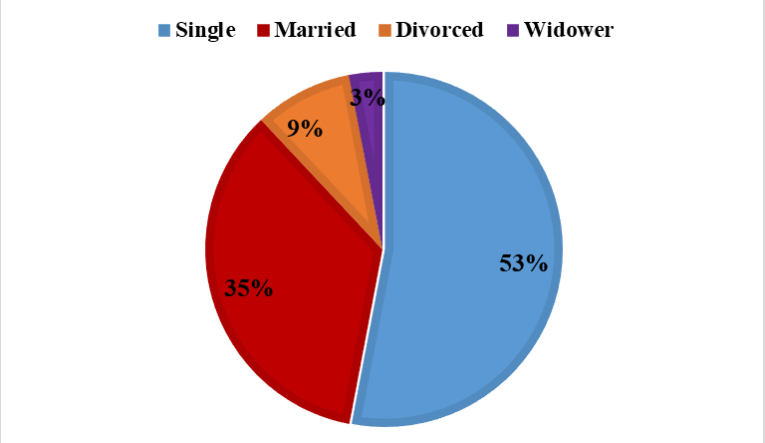


*Fig. 1. What is your marital status?*

Figure 1 shows the distribution of nurses surveyed according to their marital status. It also provides important information about the social context in which they pursue their professional careers. The observed distribution shows a predominance of individuals with an established marital status (married), along with a significant proportion of unmarried respondents.

This can be interpreted as an indicator of relative stability in the social and personal lives of many of the respondents, which is directly related to their professional development and retention in the field. Marital status is often associated with a greater need for security, a stable income, and predictability in the work environment. This may explain why many nurses choose careers in the healthcare system despite the well-known difficulties and heavy workload of the profession.

At the same time, the proportion of single nurses should not be considered insignificant. This group is often characterized by higher mobility and readiness for professional change, including migration or a change in work environment. In this sense, the results in Figure 1 can be linked to different strategies for professional fulfillment, depending not only on individual motivation, but also on the life stage of the respondents.

In this context, the presented results highlight the significance of family status in influencing nurses' professional decisions and fulfillment. The results highlight the need for differentiated management and personnel policies that consider the various social backgrounds of nurses. Offering flexible work schedules, opportunities to balance professional and family obligations, and a supportive work environment can lead to greater satisfaction and the long-term retention of staff in the healthcare system.

Fig. 2 presents the answers of the surveyed students to the question "What is your education so far?". 44% answer secondary, 33% answer that they have acquired secondary specialised education, 5% or 8 respondents answer that they have a specialisation, 18% or 31 of the 174 respondents indicated that they had completed another higher education program before beginning their nursing studies. Many of the students and subsequent practicing nurses choose nursing not directly after completing their secondary education, but after an initial professional/personal career, or as a conscious desire for a "new beginning" (career change), realizing that it is "their time" [9]. Students who choose this specialty after already having completed higher education have different motivations; they do not simply want to "get a diploma," but to change their profession in search of satisfaction and a lasting vocation.

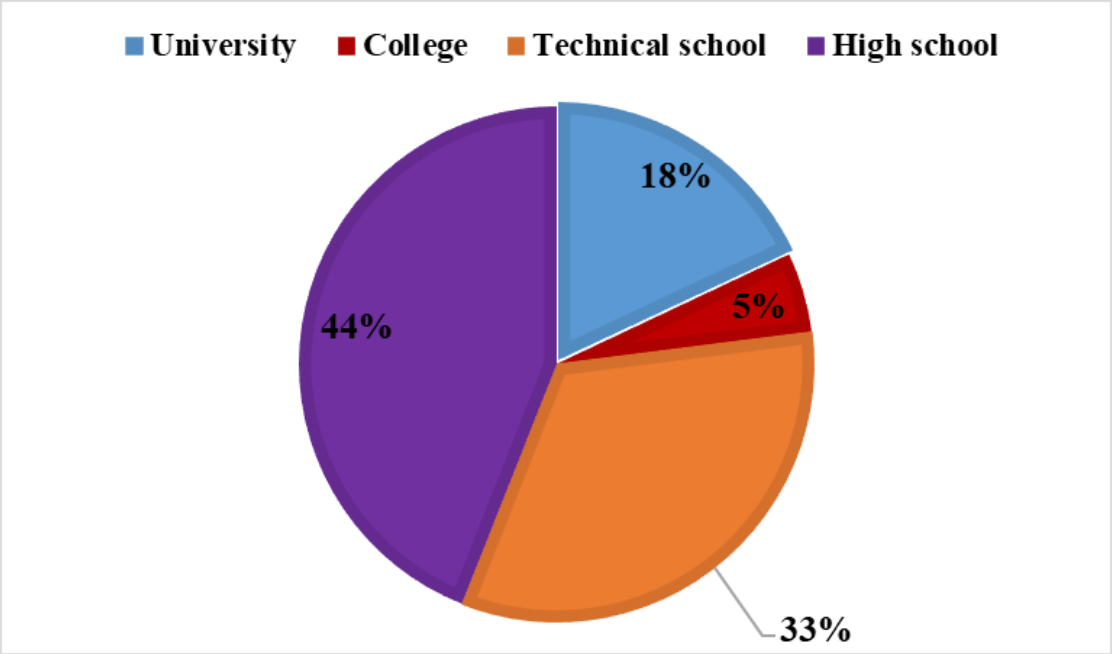


*Fig. 2. What is your education to date?*

Figure 2 shows the educational profile of students at the time they enrolled in the nursing program. The distribution of responses indicates a variety of educational trajectories and heterogeneous academic and professional experience among the study group.

The predominance of students who have completed secondary education highlights the traditional path into the nursing profession and underscores the specialty's role as a primary choice for professional development in healthcare. This group typically starts professional development earlier and is more willing to build a long-term career within the system.

Additionally, the presence of students who have already obtained higher or secondary education is a significant analytical focus. This result can be interpreted as an indicator of a conscious professional choice and reorientation toward a profession with clear social significance and stable realization. In these cases, training to become a nurse is not an initial educational choice, but rather a strategic decision related to the search for professional security, real employment, and the practical application of acquired knowledge.

The heterogeneous educational backgrounds of students imply different expectations regarding the learning process and future professional realization. Students with prior education often have accumulated

academic or professional experience, which can facilitate their adaptation to the university environment and clinical practice. However, it can also make them more critical of the content and organization of training.

Regarding the professional development of nurses, the results presented here highlight the significance of educational background in influencing adaptation to the profession, career expectations, and satisfaction levels. The results highlight the need for flexible educational approaches that consider students' diverse backgrounds and foster the development of professional competencies.

Figure 2 supplements the overall picture of professional realization by demonstrating that the nursing profession appeals to young individuals without prior academic experience and to those with an established educational background. This diversity should be viewed as a resource that can contribute to the sustainable development of nursing staff, provided adequate educational and organizational strategies support it.

To examine the respondents' attitudes toward their future careers, they were asked, "In which town would you like to pursue your career after graduation?" (Fig. 3).

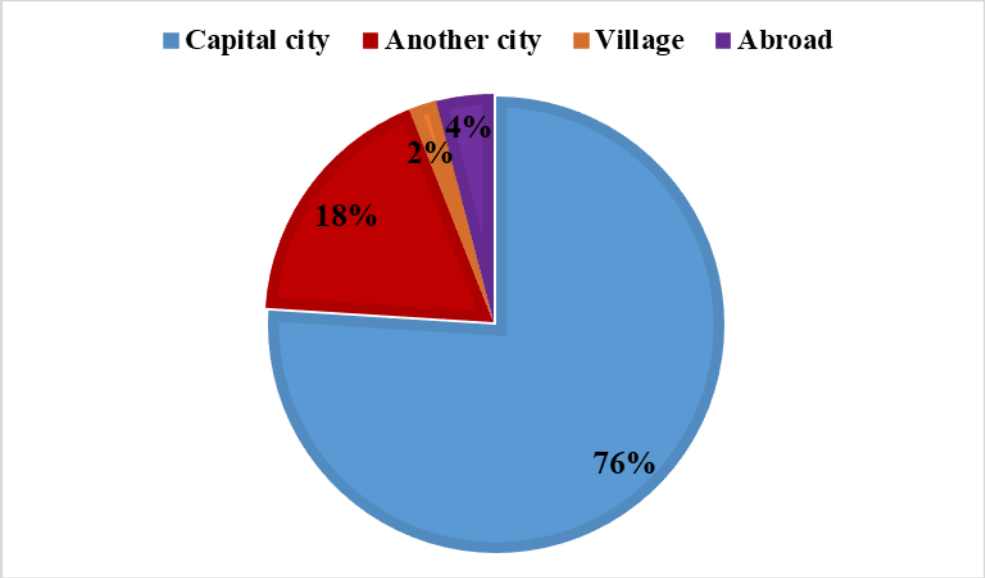


*Fig. 3. In which town would you like to pursue your career after graduation?*

The results presented in Figure 3 outline the preferences of nursing students regarding the type of settlement in which they would like to pursue their career after graduation. 76% or 130 of them respond that they intend to pursue their career in the capital, 18% or 32 intend to work in another city, 4% or 7 respondents say they intend to work abroad, and only 2% or three respondents say they intend to work in a village. The observed pattern shows a division between preferences for large cities, medium-sized cities, and small towns/villages, which reflects both individual expectations and perceptions of working and living conditions.

Analysis of these data shows that a significant proportion of respondents prefer to pursue their careers in larger urban centers. This can be explained by the wider opportunities for professional development, better working conditions, the variety of specializations, and the availability of larger healthcare institutions that provide opportunities for different career paths. For young professionals, cities are often associated not only with professional prospects, but also with the social environment, education, and opportunities for personal development.

The variability in preferences for medium-sized and small towns is also significant. Although they are not the leading choice for most respondents, the presence of students who indicate this type of settlement is not insignificant. The trend may reflect both a personal willingness to work in areas closer to the family environment and opportunities related to certain types of health services outside the major centres.

This dynamic in preferences is consistent with international empirical studies showing that job location is a key component of healthcare professionals' career decisions and is strongly influenced by a combination of personal and organizational factors. For example, a study conducted among registered nurses in the US found that when choosing between positions in urban and more remote (rural) areas, key factors are not only remuneration, but also a supportive work environment, autonomy, and the presence of a cohesive team, with location playing a role in the search for these characteristics and influencing the overall choice of workplace [10].

From the perspective of health systems, preferences for urban jobs can also be linked to the greater concentration of infrastructure, technological resources, and specialized services in large centers, which in turn facilitates practice and continuing professional education. This is particularly important for specialties where constant access to modern clinical practices is a prerequisite for maintaining high professional standards.

At the same time, international literature highlights the challenges of attracting and retaining nurses in smaller and rural areas, where structural resources and social services are often lacking, making it difficult to settle and pursue a long-term career. Thus, health human resource planning strategies include both economic incentives and improvements in working conditions and the living environment in these areas to increase their attractiveness to health professionals [11].

It is important to note that preferences regarding place of residence are not only a matter of personal choice; they often reflect deeper structural factors, such as the quality of health services, the availability of training and specialization opportunities, living conditions, career prospects, and social support. Therefore, the results in Figure 2 describe current attitudes and outline important political and organizational challenges for health systems.

Figure 4 shows the responses to the question, "Where would you like to work after graduation?"

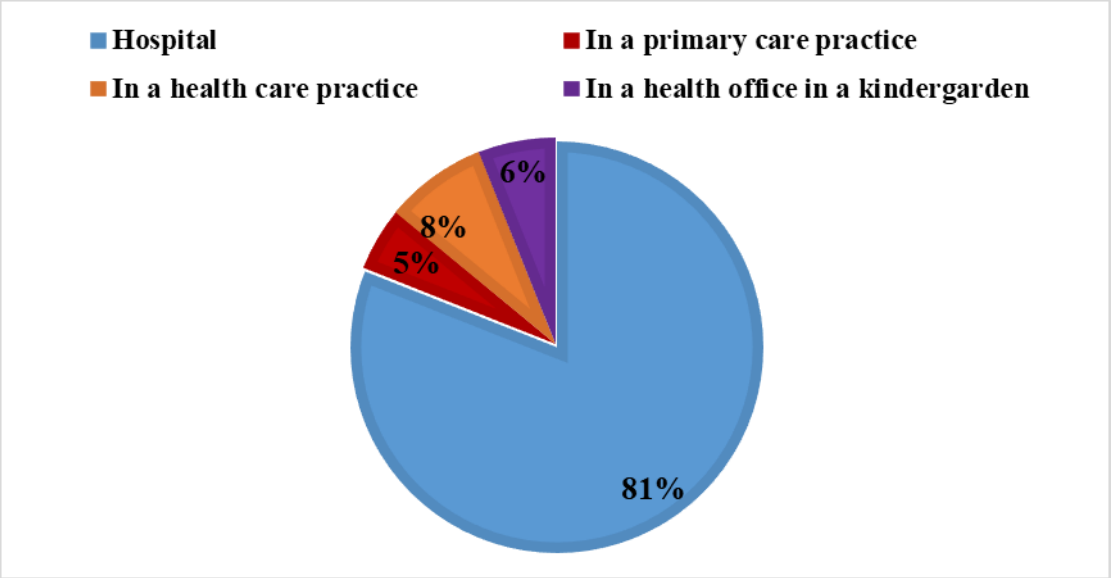


*Fig. 4. Where would you like to work after graduation?*

Figure 4 illustrates nursing students' attitudes about where they would like to work after graduation. The distribution of responses shows varying preferences among students regarding their future careers. Eighty-one percent of respondents indicated that they would like to work in hospitals. Eight percent indicated that they would like to work in outpatient care facilities. Six percent indicated that they would like to work in health offices in nurseries or kindergartens. Five percent responded that they would like to work in individual healthcare practices.

One of the key trends that stands out is the clear orientation towards inpatient care facilities. This choice may be influenced by the perception that these environments provide stable employment, better material and professional support, as well as opportunities for specialization and professional development within the system. Similar attitudes were observed in a study conducted among nursing students in Italy, where the majority preferred to work in inpatient care facilities, specifically in clinical areas such as pediatrics, emergency departments, and operating rooms. These preferences remain consistent throughout their years of study and reflect stable patterns of career attitudes related to clinical practice [12].

Job preferences are also often linked to the clinical experience students gain during their training. Research shows that students often choose job positions that resemble those in which they were trained or developed valid professional skills during their internships, which has also been found in the context of choosing between the public and private sectors in other countries [13]. This trend can be explained by the greater sense of security and competence in performing professional tasks in an environment that is familiar from the learning process.

On the other hand, it is possible that some students prefer jobs outside the traditional hospital setting, and such choices may be motivated by personal beliefs about the importance of healthcare in a broader social context, a desire for work-life balance, or a search for more dynamic and patient-oriented roles. The career of nurses is not limited solely to hospital structures – a study focused on home care shows that factors such as job quality, independence, and satisfaction with patient relationships have a strong influence on the choice of working environment in community care areas [14].

It is important to note that the choice of where to work after graduation is not just a matter of professional preference but reflects a broader range of expectations and assessments of the future work environment. This includes perceptions of working conditions, opportunities for continuing education, interaction with colleagues and patients, and opportunities for professional and personal development. Factors such as working hours, geographical location, working conditions, and training opportunities have a strong influence on the preferences of medical professionals when choosing a job, and not just the characteristics of the workplace itself [15].

Figure 4 shows that students' preferences for where to work after graduation are multifaceted. They include a desire for job security and professional development in clinical settings, as well as potential interest in more specialized or community-based roles. This pattern of attitudes provides valuable information for educational institutions and healthcare policymakers interested in directing future nursing staff toward areas with the greatest need for skilled labor.

To examine attitudes toward continuing education after nursing school, respondents were asked, "Do you plan to continue your education after obtaining a bachelor's degree?" (Fig. 5).

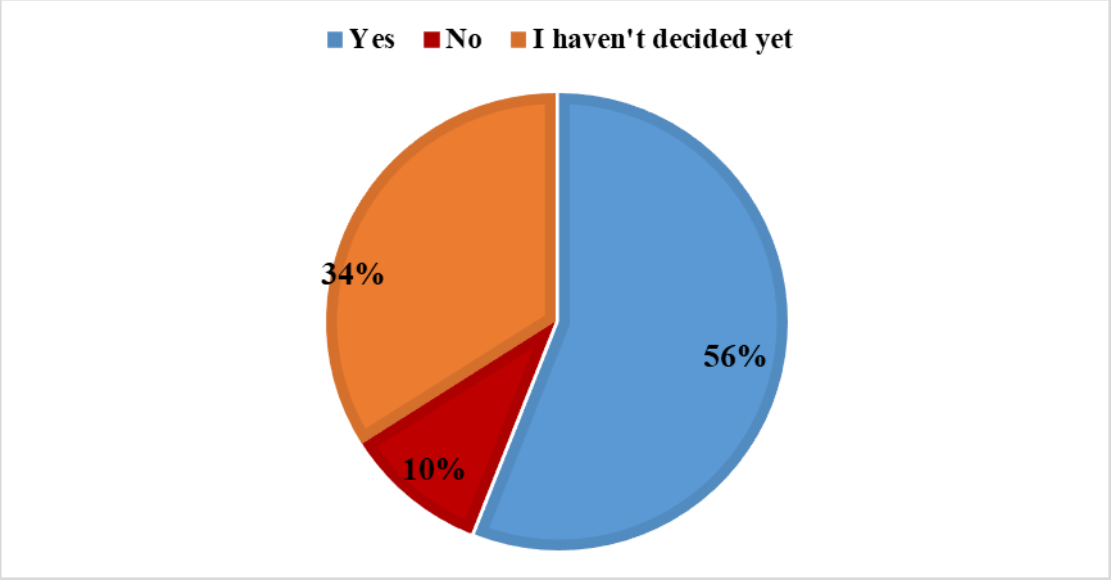


*Fig. 5. Do you plan to continue your education after obtaining a bachelor's degree?*

Figure 5 shows the results of a survey of nursing students regarding their intention to continue their education after obtaining a bachelor's degree. Of the respondents, 56% said they would continue their education, 34% said they had not yet decided, and 10% said they did not intend to do so. These results suggest a significant proportion of students plan to further their education, indicating a desire for professional development and improvement of competencies in the field of healthcare.

The willingness to continue education after graduation is in line with established international trends, according to which nurses increasingly perceive additional qualifications as a key factor for career advancement, professional autonomy, and participation in more specialized clinical, managerial, or educational roles. A survey of registered nurses and midwives found that a significant proportion of respondents expressed a strong intention to continue their education, motivated by a desire to improve their professional skills and expand their opportunities for realization [16].

These results can also be viewed in the context of changing requirements for the nursing profession related to increasing care complexity, new technologies, and interdisciplinary work. Continuing professional and academic training is essential for maintaining the quality of healthcare and adapting nurses to the dynamics of healthcare systems.

However, not all students are willing to pursue continuing education, possibly due to financial constraints, the need for rapid entry into the labor market, family commitments, or a lack of clear prospects for professional growth after obtaining an additional qualification.

Figure 5 shows significant potential for academic and professional development among nursing students. Providing accessible, flexible continuing education and a clear link between higher qualifications and career advancement could encourage more future nurses to invest in their education and professional development.

**Conclusions**

The results of an empirical study conducted among nursing students at the Faculty of Public Health at the Medical University of Sofia reveal clearly expressed attitudes and trends regarding their future professional realization. The data show that the choice of the nursing profession is largely conscious and motivated, with students demonstrating a desire for professional security and development within the healthcare system.

Preferences for professional realization are strongly concentrated in large urban centers, particularly in the capital, confirming the existence of persistent regional imbalances in the distribution of nursing staff. The limited interest in working in small towns and rural areas highlights the need for targeted policies to encourage and retain nurses in regions with a shortage of healthcare professionals.

Regarding the working environment after graduation, there is a dominant orientation toward hospital care facilities, which can be explained by perceived opportunities for professional development, specialization, and greater organizational security. The weaker interest in outpatient care and community health highlights the need for these sectors to be more actively presented in the educational process and career guidance of students.

A significant focus of the study is attitudes toward continuing education. More than half of the respondents stated their intention to continue their education after completing their bachelor's degree, while a significant proportion expressed hesitation, indicating the potential for academic and professional development. These results underscore the importance of continuing education in enhancing professional competence and adapting to the evolving demands of the healthcare system.

In conclusion, this study shows that, while nursing students are highly motivated to realize and develop their careers, their attitudes do not fully correspond to the structural needs of the national healthcare system. An integrated approach combining educational, staffing, and social measures is necessary for sustainable development and an even distribution of nursing staff throughout the country.

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# WHEN PLATELETS RISE: A PRACTICAL APPROACH TO THROMBOCYTOSIS IN DAILY CLINICAL PRACTICE

***Sapunarova K.***
*First Department of Internal Diseases, Division of Hematology, Medical University of Plovdiv, Chief Assistant Professor, PhD, Bulgaria;*
*Clinic of Clinical Hematology, University Hospital "Sv. Georgi," Plovdiv, Bulgaria*
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**ABSTRACT**

Thrombocytosis is a hematologic condition characterized by an elevated platelet count in the peripheral blood above the upper age-adjusted reference limit, typically >450 × 10⁹/L. It is broadly classified as primary (clonal), most commonly associated with myeloproliferative neoplasms such as essential thrombocythemia, and secondary (reactive), occurring in response to infections, inflammatory disorders, iron deficiency anemia, tissue injury, malignancy, or following splenectomy. In daily practice, reactive thrombocytosis predominates and is generally transient with a benign clinical course. The clinical significance of thrombocytosis depends not only on the degree of platelet elevation but also on the underlying condition, platelet function, and coexisting risk factors. While secondary forms are rarely associated with major complications, primary thrombocytosis carries an increased risk of thrombotic and hemorrhagic events, as well as the potential for progression to myelofibrosis or acute leukemia. Timely differentiation between reactive and clonal forms is essential for appropriate therapeutic decision-making and long-term prognostic assessment.

**Keywords:** thrombocytosis, inflammation, iron deficiency, myeloproliferative neoplasms, clonal diseases.

**Introduction**

Thrombocytosis is an abnormality defined as an increase in the platelet count in peripheral blood above 450 × 10⁹/L. It is observed in a wide range of conditions, including both benign disorders and clonal hematologic diseases. In clinical practice, it is often detected incidentally in asymptomatic patients and raises the question of the seriousness of its underlying cause. In many cases, the diagnostic process requires time to accurately distinguish between a reactive process and a clonal etiology. In addition to identifying the cause, assessing the potential risk of complications (most commonly thrombotic events) is of significant importance. The contemporary diagnostic approach to thrombocytosis is based on a combination of clinical findings, basic laboratory parameters, and specialized molecular genetic investigations, which enable timely diagnosis and appropriate clinical management.

This review provides a practice-oriented overview of the most common types of thrombocytosis, aiming to facilitate the work of specialists from various fields by presenting the most important clues leading to its underlying causes, the relevant diagnostic methods, and a simplified management algorithm for everyday clinical practice.

**Classification of Thrombocytosis**

Depending on the underlying causes, thrombocytosis can be classified into the following groups:

**I. Reactive (Secondary) Thrombocytosis**

This is the most common form and represents a physiological response of the bone marrow to external stimuli. It occurs more frequently and accounts for approximately 80–90% of all cases of thrombocytosis in clinical practice [1]. The main causes of reactive thrombocytosis include acute and chronic infections, inflammatory and autoimmune diseases, iron deficiency anemia, solid tumors and hematologic malignancies, postsurgical states and splenectomy, blood loss, and hemolysis. The most significant characteristics of these conditions are their transient nature, absence of clonal mutations, and low thrombotic risk, with management primarily directed toward treatment of the underlying disease.

**II. Clonal Thrombocytosis**

This form is associated with myeloproliferative neoplasms, in which thrombocytosis results from autonomous megakaryocytic proliferation without external stimulation. The main nosological entities in this group include essential thrombocythemia(ET), polycythemia vera(PV), and primary myelofibrosis (PMF), including the prefibrotic phase. These conditions are characterized by persistent thrombocytosis driven by mutations in genes such as JAK2, CALR, and MPL, an increased risk of arterial and venous thrombosis, and a paradoxical risk of hemorrhagic complications in cases of extreme thrombocytosis.

**III. Hereditary (Familial) Thrombocytosis**

This group includes very rare genetically determined conditions characterized by mutations in the THPO or MPL genes, absence of malignant potential, and diagnosis typically established in childhood or early adulthood. The clinical significance of thrombocytosis is primarily determined by the assessment of the risk of thrombotic and hemorrhagic complications, as well as the risk of clonal evolution in cases of underlying hematologic malignancy. Misinterpretation of thrombocytosis carries a dual risk: unnecessary treatment on one hand, and failure to diagnose a serious underlying condition on the other. Underestimation may delay the diagnosis of a myeloproliferative neoplasm, whereas overdiagnosis in reactive forms may lead to unjustified antithrombotic or cytotoxic therapy.

To reduce the risk of diagnostic errors, the evaluation of thrombocytosis requires a structured diagnostic approach that enables rapid differentiation between reactive and clonal forms, accurate risk assessment, and appropriate clinical management. This makes thrombocytosis a significant diagnostic and therapeutic challenge, with a direct impact on patient prognosis and quality of life.

**Epidemiological Data**

**Epidemiology of Reactive Thrombocytosis**

In hospital practice, the frequency of reactive thrombocytosis is particularly high and is observed in approximately 1.5–7% of all hospitalized patients, with the majority of cases associated with acute infectious or inflammatory conditions [2], predominantly bacterial infections, especially in adult patients [1]. A significant proportion of benign thrombocytosis is due to iron deficiency anemia, which accounts for 15–30% of cases. This type of thrombocytosis is more commonly observed in women of reproductive age and in patients with chronic blood loss, and is considered to result from increased thrombopoietin production and dysregulation of the megakaryocytic lineage [3]. Postoperative conditions, particularly following splenectomy, represent another cause of reactive thrombocytosis. Transient thrombocytosis develops in more than 70% of patients after splenectomy, and in most cases follows a self-limiting course within several months after surgical removal of the spleen. In the pediatric population, benign thrombocytosis predominates, with more than 95% of cases in childhood being secondary in nature, most commonly associated with infections, and generally without long-term clinical consequences [4].

**Epidemiology of Clonal Thrombocytosis**

Clonal causes of persistent thrombocytosis are most commonly associated with the classical BCR-ABL1-negative myeloproliferative neoplasms, including ET, PV, and PMF. Epidemiological data indicate that the incidence of PV ranges between 0.5 and 4.0 cases per 100,000 person-years, while ET has a slightly higher incidence of approximately 1.1 to 2.0 cases per 100,000 person-years [5]. This wide range reflects diagnostic limitations across different geographical regions. In the United States, the incidence of ET has been reported at approximately 1.5 new cases per 100,000 individuals, which is comparable to data from other Western populations [6]. The median age at diagnosis is around 60 years, and the condition is rare in younger individuals. Women are more frequently affected, with a female-to-male ratio of approximately 2:1 in some larger series [7]. PMF occurs less frequently, with an incidence of approximately 0.3 to 2.0 cases per 100,000 person-years. Its clinical course often includes progressive bone marrow fibrosis, cytopenias, and an increased risk of transformation to acute leukemia, resulting in significantly shorter overall survival compared with ET and PV [8].

**Management of benign (reactive) thrombocytosis**

In reactive thrombocytosis, the main therapeutic principle is directed toward treatment of the underlying condition rather than directly targeting the platelet count. In most cases, the elevation in platelet count represents a physiological compensatory response and does not require specific hematological therapy. In the presence of acute or chronic inflammation, infection, or tissue injury, the platelet count usually normalizes in parallel with resolution of the underlying process. In these situations, the routine use of antiplatelet agents is not indicated, as it has not been shown to reduce the risk of thrombosis and may increase the risk of bleeding. Particular attention is required in cases of thrombocytosis associated with iron deficiency anemia. In this context, correction of iron deficiency leads to gradual normalization of the platelet count. Persistence of thrombocytosis after adequate treatment of iron deficiency necessitates re-evaluation and exclusion of a concomitant clonal disorder. In patients with malignancies or following splenectomy, thrombocytosis is often part of a broader prothrombotic profile. In such cases, the decision to initiate antithrombotic prophylaxis should be based on an overall assessment of vascular risk rather than on the platelet count as an isolated parameter.

In summary, in benign forms, the key management approach includes observation, treatment of the underlying condition, and avoidance of unnecessary pharmacological intervention unless additional risk factors are present.

**Clinical Significance and Management of Clonal Thrombocytosis**

The clinical significance of clonal thrombocytosis is determined by two main factors: an increased thrombotic risk and the potential for clonal evolution of the disease, which varies depending on the associated hematologic malignancy. ET is associated with a significantly increased risk of arterial and venous thrombosis. Additionally, platelets in ET exhibit functional abnormalities that not only increase thrombotic risk but are paradoxically also associated with hemorrhagic manifestations. When platelet counts exceed $1000 \times 10^9$/L, they may acquire the capacity to absorb and eliminate the activity of von Willebrand factor (vWf), leading to an acquired coagulopathy.

In PV thrombotic risk is further increased by changes in hematocrit levels and the presence of the JAK2 mutation. PMF, which has the most unfavorable clinical course among Philadelphia-negative myeloproliferative neoplasms, is characterized by a pronounced tendency for rapid progression to acute leukemia and reduced survival. It represents a diagnostic challenge, particularly in its early prefibrotic phase, when the only manifestation may be mild, seemingly benign thrombocytosis.

Table 1 summarizes the most common causes of thrombocytosis in clinical practice and their main characteristics.

Table 1

Thrombocytosis by nosological groups – etiology, mechanisms, and clinical features

| Nosological Group | Type of Thrombocytosis | Main Mechanism | Typical Clinical Features | Thrombotic Risk |
|---|---|---|---|---|
| Inflammatory and infectious diseases | Reactive | Cytokine-mediated stimulation (IL-6 → ↑ thrombopoietin) | Correlation with inflammatory activity; normalization with treatment | Low |
| Iron deficiency anemia | Reactive | Increased megakaryocyte sensitivity to thrombopoietin; compensatory hematopoiesis | Often moderate to marked thrombocytosis; possible coexistence with other causes | Usually low |
| Malignancies (solid tumors) | Reactive / Paraneoplastic | Cytokines, growth factors, tumor-induced thrombopoiesis | Associated with poorer prognosis | Moderate |
| Post-splenectomy state | Reactive | Reduced sequestration and increased platelet survival | Often pronounced in the early postoperative period | Moderate |
| Myeloproliferative neoplasms (ET, PV, PMF, CML) | Clonal | Autonomous megakaryocytic proliferation (JAK2, CALR, MPL) | Persistent thrombocytosis, splenomegaly, microvascular symptoms | High |
| Hereditary thrombocytosis | Clonal / Genetic | Mutations in genes related to the thrombopoietin pathway | Rare; often positive family history | Variable |

A major challenge in clinical practice is how to rapidly differentiate reactive thrombocytosis, which carries a low thrombotic risk, from clonal thrombocytosis, which is associated not only with an increased thrombotic risk but also with the potential for clonal evolution. Figure 1 represents a simlified approach to the diagnosis of thrombocytosis.

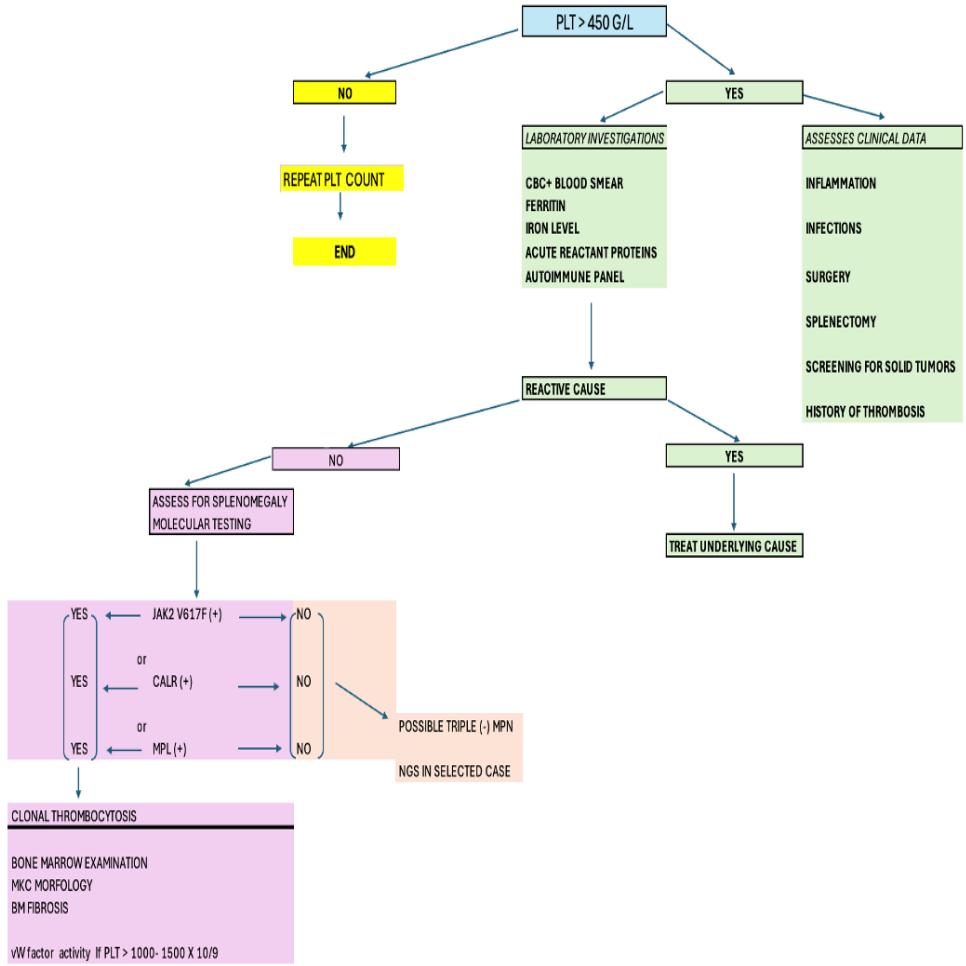


*Figure 1. Simplified Diagnostic algorithm in thrombocytosis Abbreviations: CBC- complete blood count; PLT- platelets; Jak(Janus Kinase); CALR(Calreticulin), MPL(Myeloproliferative leucemia oncogene); NGS (Next generation sequencing); MKC-megacaryocyte; vW- von Willebrand factor*

The main distinguishing features between reactive and clonal thrombocytosis are outlined in Table 2.

Table 2

Reactive versus Clonal Thrombocytosis – Key Differences

| Characteristic | Reactive (Secondary) Thrombocytosis | Clonal (Primary) Thrombocytosis |
|---|---|---|
| Underlying cause | Response to a systemic stimulus (inflammation, infection, iron deficiency, tumor) | Autonomous megakaryocytic proliferation |
| Nature of the process | Polyclonal, compensatory | Monoclonal, neoplastic |
| Duration | Usually transient | Persistent |
| Platelet count level | Moderately elevated | Markedly and persistently elevated |
| Inflammatory markers (CRP, ESR) | Often elevated | Normal |
| Iron status | Often deficient | Normal |
| Molecular markers (JAK2, CALR, MPL) | Negative | Frequently positive |
| Bone marrow findings | Reactive megakaryocytosis | Atypical megakaryocytic proliferation with clustering in MF |
| Splenomegaly | Rare | Common |
| Thrombotic risk | Low | Moderate to high |
| Hemorrhagic risk | Minimal | Increased (at very high platelet counts) |
| Management | Treatment of the underlying condition | Risk stratification and specific therapy |

**Clinical risks in thrombocytosis – When does an elevated platelet count matter?**

The risk of thrombotic complications is highly dependent on the underlying etiology of thrombocytosis. In reactive forms, it is generally low and primarily determined by the underlying condition rather than by the platelet count itself. Inflammation, infections, or iron deficiency anemia rarely lead to thrombosis directly related to thrombocytosis. Exceptions include conditions such as active malignancy, severe systemic inflammation, or post-splenectomy status, in which thrombocytosis may contribute to the overall prothrombotic risk (for example, patients with intermediate forms of thalassemia following splenectomy are at increased risk of thrombotic events).

From the perspective of absolute platelet count, mild to moderate thrombocytosis is usually not associated with an immediate clinical risk, particularly when transient and attributable to a clearly reactive cause. Its clinical significance increases in cases of persistent and marked elevation exceeding $1000 \times 10^9$/L. In extreme thrombocytosis, the risk becomes more complex—along with thrombosis, the likelihood of bleeding also increases. Platelets exert functional effects that sustain systemic inflammation, creating a vicious cycle in which platelets perpetuate the inflammatory process, which in turn leads to increased platelet production. Microvascular symptoms such as erythromelalgia and transient neurological complaints may be considered early warning signs, where platelet activation and inflammation result in functional disturbances of the microcirculation without structural thrombosis.

In this context, decisions regarding antiplatelet and cytoreductive therapy cannot be based solely on platelet count but should take into account inflammatory activity, signs of hemostatic disturbance, and individual vascular risk. It is particularly important to recognize situations in which aggressive antithrombotic therapy may increase hemorrhagic risk, as well as the opposite scenario—underestimation of thrombotic risk in patients with relatively moderate thrombocytosis but increased platelet activity.

In contrast, in clonal thrombocytosis, platelets are often functionally altered and actively participate in the thrombotic process. Another important aspect is their functional heterogeneity. In clonal thrombocytosis, platelets are not only increased in number but also exhibit a greater tendency toward activation, adhesion, and interaction with the endothelium. This explains why thrombotic risk does not correlate linearly with the absolute platelet count and why some patients develop vascular events at relatively moderate levels. Arterial and venous thromboses, including stroke, myocardial infarction, and thromboses in atypical vascular territories, represent a major source of morbidity. The risk is further increased in older patients, those with a history of previous thrombotic events, and in the presence of specific molecular characteristics (e.g., JAK2 positivity).

Clinical attention should also be given to the hemorrhagic risk associated with very high platelet counts exceeding $1200 \times 10^9$/L. In such cases, an acquired deficiency of vWf often develops, clinically manifesting as mucocutaneous bleeding, epistaxis, or gastrointestinal hemorrhage.

**Clinical Indicators of Clonal Thrombocytosis**

In clinical practice, several “red flags” warrant increased suspicion of clonal thrombocytosis. Alarm features include:

1. persistent thrombocytosis for more than 6 months without a clear reactive cause;
2. splenomegaly;
3. microvascular ischemia of the extremities;
4. increasing platelet count or values exceeding $1000 \times 10^9$/L.

**Therapeutic Approach to Clonal Thrombocytosis**

Management is a process in which the appropriate approach is guided by addressing several key questions:

1. ***What should be the treatment goal?***

In clonal thrombocytosis, the objective is not merely to reduce platelet count, but to:

- decrease thrombotic risk (arterial/venous thrombosis);
- limit hemorrhagic risk (especially in extreme thrombocytosis and acquired von Willebrand disease);
- control microvascular symptoms (headache, erythromelalgia, visual disturbances).

2. ***Who requires active therapy?***

This decision is based on risk factors for thrombotic events. According to current reviews and recommendations for ET, risk is stratified into four categories—very low, low, intermediate, and high—based on age, history of thrombosis, JAK2 mutation status, and other factors [6,9]. Table 3 summarizes management strategies regarding both antiplatelet and cytoreductive therapy in clonal thrombocytosis.

**Table 3**

Practical approach to risk stratification and management of essential thrombocythemia (ET)

| Risk Group | Criteria | Recommended Therapeutic Strategy |
|---|---|---|
| High risk | Age ≥60 years and/or history of arterial or venous thrombosis | Cytoreductive therapy (first-line: hydroxyurea; alternative: interferon-α); Antithrombotic therapy (low-dose aspirin, if no contraindications); Strict control of cardiovascular risk factors |
| Low risk | Age <60 years and no history of thrombosis | Low-dose aspirin, if no contraindications (especially in JAK2 V617F-positive patients); Control of cardiovascular risk factors; Cytoreduction is not routinely indicated but may be considered in cases of extreme thrombocytosis, symptomatic microvascular ischemia, or acquired von Willebrand syndrome |

The table systematizes therapeutic management according to the risk of vascular complications.

3. ***When should aspirin be used with caution or avoided*****?** One of the most common clinical questions concerns the use of aspirin—when it should be administered and when it should be avoided. Low-dose aspirin is standard therapy for many patients with ET/PV, particularly in the presence of microvascular symptoms and/or increased arterial risk, except in cases with an elevated bleeding risk [10,11]. Discontinuation of aspirin should be considered in cases of extreme thrombocytosis (approximately >1000–1500 × $10^9$/L) due to the risk of acquired von Willebrand syndrome (avWS) [10,12]. A practical rule in patients with very high platelet counts is to first exclude avWS. A second practical approach is to initiate cytoreductive therapy before implementing an antiplatelet strategy.

4. ***Cytoreductive therapy*** represents the cornerstone of management in patients at high thrombotic risk. Table 4 summarizes the indications for initiating cytoreductive treatment [6].

If thrombocytosis is part of PV/PMF, platelet count should be managed within the framework of overall PV therapy [13]. In PV, achieving hematocrit control in combination with an antiplatelet strategy is essential. In PMF, management may include JAK inhibitors when indicated, with thrombocytosis treated according to the individual risk profile and clinical presentation.

Table 4.

Indications and therapeutic options for cytoreduction in clonal Thrombocytosis

| Category | Indication / Therapeutic Option | Clinical Notes |
|---|---|---|
| Indications for initiation of cytoreduction | High thrombotic risk | Advanced age and/or history of prior thrombosis |
| | Intolerance or contraindications to aspirin | Increased thrombotic risk in the absence of antiplatelet prophylaxis |
| | Extreme thrombocytosis | Risk of bleeding (acquired von Willebrand syndrome) and thrombosis |
| | Perioperative conditions | Additional transient thrombotic risk |
| | Pregnancy | Individual risk–benefit assessment |
| First-line therapy | Hydroxyurea | Most commonly used in high-risk patients, especially those >60 years of age |
| | Pegylated interferon-α | Preferred in younger patients and in planned or established pregnancy; suitable for long-term control without HU |
| Alternative / Second-line | Anagrelide | In cases of intolerance or contraindications to HU/IFN; requires caution due to cardiovascular adverse effects |

**Emergency Situations**

In cases of symptomatic extreme thrombocytosis accompanied by acute thrombotic complications or severe bleeding associated with avWS, rapid platelet reduction by thrombocytapheresis may be required as a bridge to subsequent cytoreductive therapy. AvWS is one of the frequently underestimated complications in clonal thrombocytosis. The pathophysiological basis of avWS in clonal thrombocytosis is related to the markedly elevated platelet count and the accelerated adsorption and clearance of high-molecular-weight vWF multimers from the platelet surface. As a result, a functional deficiency of vWF develops, resembling type 2 von Willebrand disease, with impaired primary hemostasis.

Clinically, avWS presents with mucocutaneous bleeding manifestations such as epistaxis, gingival bleeding, easy bruising, and gastrointestinal hemorrhage [12]. The risk of bleeding is highest in patients with extreme thrombocytosis, usually at platelet counts exceeding 1000–1500 × $10^9$/L, and is significantly more common in clonal than in reactive forms. The presence of avWS has important implications for therapeutic decision-making. In such cases, routine use of antiplatelet therapy, particularly aspirin, may lead to clinically significant bleeding and should be avoided until platelet count is reduced. Therefore, in patients with very high platelet counts in the context of clonal thrombocytosis, targeted assessment of vWF activity and multimer analysis is recommended prior to initiating antiplatelet therapy. Treatment of avWS in myeloproliferative neoplasms is primarily directed at the underlying disease.

In conclusion, thrombocytosis is a heterogeneous condition. Differentiation between reactive and clonal forms, assessment of associated clinical phenomena, and integration of thrombotic, hemorrhagic, and inflammatory risk are essential for optimal clinical management. Understanding this complex interplay is key to an individualized patient-centered approach and to optimizing therapeutic strategies in both benign and clonal forms of thrombocytosis.

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# PEDAGOGICAL SCIENCES

## THE USE OF MOLECULAR MODEL TECHNOLOGIES IN TEACHING THE TOPIC OF AMINO ACIDS AND PROTEINS

***Orujov Y.***
*Baku State University, Master's student*
***Nagiyev K.***
*Chemistry faculty, chemistry teaching methodology, head of the department, doctor of chemical sciences, professor*
*Baku State University,*
***Abishov N.***
*Doctor of Pedagogical Sciences, Professor*
*Baku State University*
*Baku, Azerbaijan*
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**ABSTRACT**

The effective teaching of amino acids and proteins is fundamental to secondary and higher-level chemistry and biology education, as these biomolecules constitute the structural and functional basis of living systems. However, the abstract nature of molecular structure, stereochemistry, peptide bond formation, and protein folding often presents conceptual challenges for students. This article explores the pedagogical potential of molecular model technologies in teaching amino acids and proteins. It analyzes traditional physical molecular models, digital three-dimensional modeling software, augmented reality (AR) and virtual reality (VR) tools, and interactive simulation platforms as innovative instructional technologies. The study discusses their theoretical foundations within constructivist, inquiry-based, and STEAM-oriented frameworks. The article proposes a methodological model for integrating molecular modeling technologies into classroom practice and evaluates their impact on conceptual understanding, spatial thinking, and scientific literacy. The findings demonstrate that molecular model technologies significantly enhance students' visualization skills, analytical reasoning, motivation, and interdisciplinary connections between chemistry and biology.

**Keywords:** Amino acids, proteins, molecular modeling, digital learning technologies, chemistry education, visualization, interactive learning, STEAM.

### INTRODUCTION

The topic of amino acids and proteins occupies a central position in the chemistry curriculum, particularly within organic chemistry and introductory biochemistry courses at the secondary and tertiary levels. These biomolecules form the molecular foundation of life: amino acids act as the monomeric units, while proteins function as highly specialized macromolecules responsible for virtually all biological processes. Structurally, proteins contribute to cellular architecture (e.g., cytoskeletal proteins), catalytically they function as enzymes accelerating biochemical reactions, and physiologically they regulate transport (hemoglobin), signaling (hormones and receptors), immunity (antibodies), and gene expression. Thus, understanding amino acids and proteins is not only essential for mastering chemistry but also for building interdisciplinary connections with biology, medicine, environmental science, and biotechnology [1, p.619].

However, despite their fundamental importance, students frequently experience significant conceptual and cognitive challenges when studying this topic. One of the primary difficulties involves understanding the general structure of α-amino acids. Although students may memorize the formula $NH_2$–CHR–COOH, they often struggle to internalize the tetrahedral geometry around the α-carbon, the presence of functional groups, and the structural variability introduced by the R-group. This superficial understanding becomes even more problematic when exploring stereochemistry. Chirality and stereoisomerism represent another major conceptual obstacle. The idea that most amino acids (except glycine) are chiral and exist in L- and D-forms requires spatial reasoning skills that many learners have not fully developed. Students may memorize definitions of enantiomers but fail to visualize mirror-image structures in three-dimensional space. Without adequate spatial representation, stereochemical concepts remain abstract and disconnected from molecular reality [2, p.109].

Peptide bond formation presents further complexity. While the condensation reaction between the amino group of one amino acid and the carboxyl group of another can be written symbolically, students often do not clearly understand the mechanistic aspects, the release of water, or the planar nature of the peptide bond. The resonance stabilization and partial double-bond character of the peptide linkage are particularly challenging to conceptualize without dynamic visualization tools. The structural hierarchy of proteins primary, secondary, tertiary, and quaternary structures—adds another layer of abstraction. Students must distinguish between: The linear amino acid sequence (primary structure), local folding patterns such as α-helices and β-sheets stabilized by hydrogen bonding (secondary structure),the overall three-dimensional conformation resulting from side-chain interactions (tertiary structure),the association of multiple polypeptide chains (quaternary structure).Each level involves different types of chemical in-

teractions, including hydrogen bonds, ionic interactions, hydrophobic effects, and disulfide bridges. Without visual and interactive representations, these hierarchical levels may appear as isolated theoretical definitions rather than interconnected structural realities [3, p.109].

Protein folding and denaturation introduce dynamic aspects that further complicate understanding. The concept that protein structure determines function, and that changes in temperature, pH, or chemical environment can disrupt weak interactions and alter conformation, requires students to integrate knowledge of intermolecular forces, thermodynamics, and biological function. In traditional lecture-based instruction, these processes are often described verbally or illustrated through static textbook diagrams, which inadequately convey the dynamic and spatial nature of folding pathways. These learning difficulties largely stem from the microscopic and three-dimensional character of biomolecular structures. Unlike macroscopic chemical experiments that students can directly observe, molecular interactions occur at a scale beyond direct perception. Chemistry education therefore relies heavily on representational models structural formulas, ball-and-stick diagrams, space-filling models, and symbolic equations. When these representations are not effectively integrated, students experience cognitive overload and fragmentation between symbolic and spatial understanding. Traditional lecture-centered approaches often emphasize memorization of definitions, reaction equations, and structural terminology. While such methods may support short-term recall, they rarely promote deep conceptual comprehension or spatial reasoning. Students may correctly answer examination questions yet remain unable to mentally manipulate molecular structures or explain structure–function relationships coherently [4, p.34].

In this context, molecular model technologies offer a powerful pedagogical alternative. By enabling students to construct, manipulate, rotate, and analyze molecular structures—either physically through model kits or digitally through three-dimensional software and interactive simulations—abstract biochemical concepts become tangible and visually accessible. Molecular modeling bridges the gap between symbolic representations and microscopic reality, strengthening connections between theoretical knowledge and spatial understanding. Moreover, these technologies align with contemporary educational paradigms such as constructivism, inquiry-based learning, and STEAM integration. When students actively build amino acid structures, simulate peptide bond formation, or explore protein folding in digital environments, they engage in experiential learning processes that enhance analytical thinking, creativity, and interdisciplinary reasoning. Therefore, the integration of molecular modeling technologies into the teaching of amino acids and proteins is not merely a technological innovation but a methodological transformation. It shifts instruction from passive transmission of information toward active conceptual construction, supporting deeper understanding, improved visualization skills, and stronger connections between chemistry and life sciences [5, p.75,6, p.112].

This article aims to provide a comprehensive pedagogical analysis of how molecular modeling technologies can be systematically integrated into the teaching of amino acids and proteins. It examines theoretical foundations, instructional strategies, technological tools, and their impact on student learning outcomes, offering a structured framework for modern chemistry education.

**MATERIALS AND METHODS**

This study employed a quasi-experimental design to evaluate the effectiveness of molecular modeling technologies in teaching the topic of amino acids and proteins. The research was conducted with 32 undergraduate students enrolled in a General Biochemistry course at Baku State University. The participants were divided into two groups: Experimental group (n = 16), which received instruction using molecular model technologies (physical model kits and 3D digital modeling software). Control group (n = 16), which received traditional lecture-based instruction supported by textbook diagrams. The intervention lasted for four weeks and included structured activities such as: Construction of α-amino acid models using physical kits, digital manipulation of 3D molecular structures, simulation of peptide bond formation, visualization of secondary and tertiary protein structures. To measure learning outcomes, pre-test and post-test assessments were administered. The tests included: Conceptual understanding questions, spatial reasoning tasks, structure–function explanation items. Additionally, student engagement was evaluated through a short reflective questionnaire.

Data were analyzed using descriptive statistical comparison of mean score differences between groups.

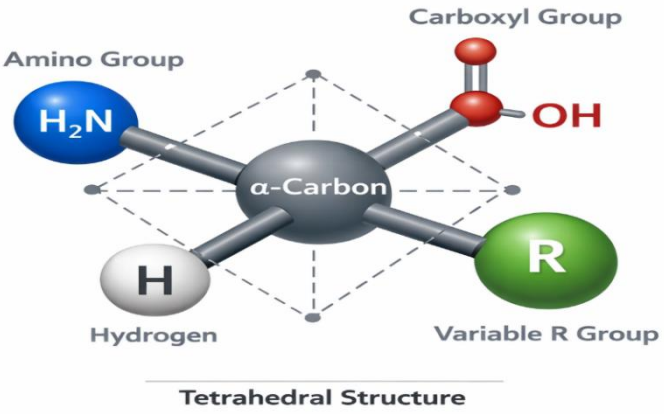


*Figure 1. General structure of an α-amino acid showing the amino group (–$NH_2$), carboxyl group (–COOH), hydrogen atom, and variable R-group attached to the tetrahedral α-carbon*

*As illustrated in Figure 1, the α-amino acid molecule consists of a central carbon atom (α-carbon) bonded to four different substituents: an amino group (–$NH_2$), a carboxyl group (–COOH), a hydrogen atom, and a variable side chain (R-group). This tetrahedral arrangement explains the three-dimensional geometry of amino acids and forms the structural basis for chirality in all amino acids except glycine. The spatial configuration of these functional groups plays a crucial role in determining chemical reactivity and biological function.*

**RESULTS**

The results demonstrated a significant improvement in the experimental group compared to the control group. Students in the experimental group showed: A 27% increase in conceptual accuracy related to stereochemistry and peptide bond formation. Improved performance in spatial reasoning tasks, particularly in identifying chiral centers and distinguishing protein structural levels. Greater ability to explain structure–function relationships in written responses.

In contrast, the control group demonstrated only a 12% average improvement in post-test scores. Furthermore, reflective questionnaires indicated higher levels of motivation and engagement among students exposed to molecular modeling technologies. Students reported that manipulating three-dimensional structures helped them better understand abstract biochemical concepts. These findings confirm that molecular model technologies positively influence conceptual clarity, spatial visualization skills, and overall academic performance in the study of amino acids and proteins.

**THEORETICAL FOUNDATIONS.**

The pedagogical integration of molecular model technologies into the teaching of amino acids and proteins is grounded in modern educational theory, cognitive science, and subject-specific didactics of chemistry. Understanding biomolecular structure requires learners to operate within abstract, multi-level representations and to develop spatial reasoning skills that are not automatically formed through traditional lecture-based instruction. Therefore, the theoretical foundations of this approach combine constructivist epistemology, representational competence theory, cognitive visualization principles, and interdisciplinary STEAM integration. Constructivist theory posits that knowledge is not transmitted directly from teacher to student but is actively constructed by the learner through interaction, reflection, and experience. In the context of amino acids and proteins, students must construct mental models of: Tetrahedral geometry around the α-carbon, three-dimensional stereochemistry, peptide bond formation mechanisms, hierarchical protein structures

When students manipulate physical molecular kits or interact with digital 3D models, they engage in experiential learning processes. This hands-on and minds-on activity supports cognitive restructuring: learners test hypotheses, correct misconceptions, and refine their internal representations. The active construction of molecular structures strengthens conceptual understanding far more effectively than passive observation of textbook diagrams. Furthermore, constructivist learning environments encourage inquiry-based questioning. For example, when students rotate a chiral amino acid model and compare mirror images, they discover stereochemical differences through exploration rather than memorization. Such experiences promote deeper cognitive processing and durable knowledge acquisition [7, p.115].

Chemistry is characterized by its reliance on multiple representational systems. Effective learning requires the ability to move fluently between three interconnected levels:

1. **Macroscopic level** – observable properties and experimental phenomena
2. **Microscopic level** – atomic and molecular structures
3. **Symbolic level** – chemical formulas, equations, and structural diagrams

Difficulties in learning amino acids and proteins often arise from an inability to coordinate these representational levels. Students may memorize structural formulas yet fail to visualize spatial conformations or understand functional implications. Molecular modeling technologies enhance representational competence

by making microscopic structures visible and dynamic. When students convert a symbolic formula (e.g., $NH_2$–CHR–COOH) into a three-dimensional structure, they bridge the symbolic and molecular levels. When they observe how structural changes influence biological function, they connect molecular representations to macroscopic biological outcomes. Thus, modeling technologies serve as cognitive mediators that unify fragmented representations into coherent conceptual systems. Research in cognitive psychology demonstrates that spatial reasoning plays a critical role in understanding complex molecular systems. Protein folding, hydrogen bonding, chirality, and tertiary structure formation all require mental rotation, depth perception, and structural comparison.

Traditional static diagrams cannot adequately support the development of these spatial skills. In contrast, three-dimensional modeling tools whether physical or digital enable dynamic manipulation. Students can rotate molecules, zoom into active sites, and observe conformational changes. Such visualization strengthens mental imagery and reduces cognitive load by externalizing complex structures. Moreover, dynamic simulations of peptide bond formation or protein denaturation allow learners to observe processes rather than merely reading descriptions. This process-oriented visualization enhances causal reasoning and mechanistic understanding. The teaching of amino acids and proteins inherently transcends disciplinary boundaries. These biomolecules represent a convergence point for multiple scientific domains:covalent bonding, functional groups, acid-base properties, enzymes, metabolism, gene expression, intermolecular forces, thermodynamics of folding, computational modeling and digital visualization. A STEAM-oriented framework promotes the integration of these perspectives into a unified learning experience. Molecular modeling technologies provide the technological platform through which interdisciplinary knowledge becomes interconnected. Students analyze chemical structure, relate it to biological function, and explore physical forces all within digital modeling environments. This interdisciplinary approach not only deepens subject knowledge but also fosters systems thinking, problem-solving skills, and scientific literacy, which are essential competencies in contemporary education. Another theoretical justification for molecular modeling lies in cognitive load theory. Amino acids and proteins involve multiple interacting variables—bond geometry, polarity, side-chain properties, folding forces which can overwhelm working memory when presented abstractly.

Interactive modeling tools distribute cognitive processing by externalizing structural information. Students no longer need to imagine complex spatial arrangements entirely in their minds; instead, they manipulate visible models. This reduces extraneous cognitive load and allows greater focus on conceptual relationships and chemical reasoning. In summary, the theoretical foundations of using molecular model technologies in teaching amino acids and proteins rest upon constructivist learning principles, representational competence development, visualization-based cognition, interdisciplinary STEAM integration, and cognitive load optimization. Together, these frameworks demonstrate that molecular modeling is not merely a supplementary teaching aid but a scientifically grounded methodological strategy for deepening conceptual understanding in chemistry education.

TYPES OF MOLECULAR MODEL TECHNOLOGIES.

The effective teaching of amino acids and proteins requires the use of diverse molecular modeling tools that address different cognitive needs and instructional objectives. Molecular model technologies can be broadly categorized into physical models, digital 3D modeling software, interactive simulations, and immersive technologies. Each type offers distinct pedagogical benefits and limitations. Among them, physical molecular model kits remain one of the most widely used and pedagogically valuable tools in chemistry education. Physical molecular model kits, including traditional ball-and-stick and space-filling models, are foundational tools in chemistry classrooms. These models allow students to construct three-dimensional representations of molecules using colored spheres (representing atoms) and connectors (representing bonds). Despite the rapid development of digital technologies, physical models continue to play a crucial role in developing spatial and structural understanding. When applied to the teaching of amino acids and proteins, physical model kits enable students to: Construct the general structure of α-amino acids, including the amino group ($–NH_2$), carboxyl group (–COOH), hydrogen atom, and variable R-group attached to the central carbon.Visualize tetrahedral geometry around the α-carbon and understand bond angles in three-dimensional space, identify and differentiate functional groups within various amino acids (e.g., acidic, basic, polar, nonpolar side chains). Demonstrate peptide bond formation by physically removing components representing water and linking amino acids through amide bonds. This tactile engagement transforms abstract formulas into tangible structures. Students can rotate, examine, and compare molecules from multiple perspectives, which strengthens their ability to mentally manipulate spatial information.

One of the primary advantages of physical molecular models is hands-on interaction. Manipulating components encourages active learning and supports kinesthetic learners who benefit from physical engagement. By assembling molecules themselves, students move beyond passive observation and take ownership of the learning process.

Physical models also significantly contribute to the development of spatial reasoning skills. Understanding chirality, stereoisomerism, and conformational differences requires mental rotation and structural comparison—skills that are reinforced through model manipulation. For example, when students construct mirror-image configurations of chiral amino acids, they directly observe non-superimposability, making the concept of enantiomers more concrete. Furthermore, these models promote active student participation and collaborative learning. Group-based model construction activities foster discussion, hypothesis testing, and peer explanation, which enhance conceptual clarity. Students can collectively analyze struc-

tural differences between glycine and alanine or explore how side-chain properties influence molecular interactions. Another advantage is conceptual simplicity. Physical models provide clear visualization of bond connectivity and molecular geometry without the distractions sometimes associated with complex digital interfaces. Despite their pedagogical strengths, physical molecular model kits also have certain limitations. Assembly can be time-consuming, particularly when constructing larger biomolecules or polypeptide chains. Classroom time constraints may restrict the depth of exploration [8, p.1799].

Additionally, physical models have limited capacity to represent dynamic processes. While they effectively illustrate static structures, they cannot easily demonstrate protein folding pathways, conformational flexibility, hydrogen bonding networks, or denaturation processes. Representing secondary and tertiary protein structures using traditional kits can be impractical or oversimplified. Another limitation concerns scale and realism. Physical models often exaggerate bond lengths and angles for clarity, which may lead to minor distortions in spatial accuracy. They also do not easily depict electron distribution, resonance effects, or partial charges.

In conclusion, physical molecular model kits remain an essential component of molecular modeling technologies in chemistry education. They provide foundational support for understanding the three-dimensional structure of amino acids and basic peptide formation through tactile and visual engagement. However, to fully address dynamic biochemical processes and complex protein architecture, physical models should be complemented with digital and interactive technologies.

**METHODOLOGICAL MODEL FOR TEACHING.**

The effective integration of molecular modeling technologies into the teaching of amino acids and proteins requires a structured, sequential instructional design. A step-by-step methodological model ensures that students gradually move from foundational conceptual understanding to higher-order analytical and structural reasoning. This staged approach aligns theoretical explanation with practical exploration and digital visualization. The first stage involves conceptual introduction. At this level, the teacher presents the general structure of α-amino acids, emphasizing the amino group (–$NH_2$), carboxyl group (–COOH), hydrogen atom, and variable R-group attached to the central carbon atom. The goal is to establish a clear theoretical framework and connect prior knowledge of functional groups to biomolecular structure. This stage provides the symbolic and structural foundation necessary for further exploration.

The second stage focuses on physical model construction. Students use molecular model kits to build simple amino acids such as glycine and alanine. Through hands-on assembly, they observe tetrahedral geometry around the α-carbon and identify differences between side chains. By comparing the structures of glycine (achiral) and alanine (chiral), students begin to recognize how small structural variations influence molecular properties. This tactile engagement strengthens spatial reasoning and deepens structural comprehension. The third stage introduces digital modeling. Using three-dimensional molecular visualization software, students rotate molecules, examine bond angles, and explore stereochemistry in a dynamic environment. At this stage, learners identify chirality, compare enantiomers, and observe molecular conformations from multiple perspectives. Digital tools extend beyond static physical models by enabling precise manipulation and measurement, thereby reinforcing representational competence.

The fourth stage involves peptide bond simulation. Through interactive digital platforms, students simulate condensation reactions between amino acids, observe the release of water, and analyze the formation of the peptide bond. This process-oriented visualization clarifies mechanistic understanding and highlights the structural and functional significance of the amide linkage. Students move from understanding individual amino acids to conceptualizing polypeptide chains. The fifth stage expands learning to protein structure exploration. Students use molecular visualization software to investigate secondary structures such as α-helices and β-sheets and examine how hydrogen bonding stabilizes these configurations. They also explore aspects of tertiary organization, observing how side-chain interactions contribute to overall protein conformation. This stage integrates chemical bonding, intermolecular forces, and biological function.

The final stage emphasizes reflection and assessment. Students respond to conceptual questions, complete modeling-based analytical tasks, and explain structure–function relationships. Assessment may include comparative analysis, digital modeling assignments, or short explanatory essays. This reflective phase consolidates knowledge, evaluates understanding, and encourages metacognitive awareness. In summary, this methodological model progresses from theoretical introduction to physical construction, digital exploration, mechanistic simulation, structural analysis, and reflective assessment. Such a structured sequence ensures cognitive continuity, promotes active engagement, and fully utilizes molecular modeling technologies to enhance conceptual understanding of amino acids and proteins.

**PEDAGOGICAL ADVANTAGES**

The integration of molecular model technologies into the teaching of amino acids and proteins offers substantial pedagogical benefits that extend beyond simple visualization. These technologies significantly enhance students' spatial reasoning abilities by allowing them to manipulate and explore three-dimensional molecular structures. As a result, learners develop stronger mental models of stereochemistry, molecular geometry, and structural hierarchy.

In addition, modeling-based instruction improves long-term retention of knowledge. When students actively construct, rotate, and analyze molecular structures, they engage multiple cognitive channels—visual, kinesthetic, and analytical—which strengthens memory consolidation. The interactive nature of these tools also increases student motivation and engagement, transforming complex biochemical content into

an exploratory learning experience. Molecular modeling technologies further support differentiated instruction. Digital platforms can be adapted to varying levels of complexity, enabling teachers to tailor tasks to students' abilities. Advanced learners may explore protein folding simulations in greater depth, while others focus on fundamental structural concepts. Moreover, modeling activities foster research and analytical skills by encouraging hypothesis formation, structural comparison, and causal reasoning. Collaborative learning is another significant advantage. Group-based modeling tasks stimulate scientific discussion, peer explanation, and collective problem-solving. Importantly, these technologies promote higher-order cognitive skills such as analysis, synthesis, and evaluation, as students must interpret structural data, relate structure to function, and assess molecular interactions critically.

**IMPACT ON STUDENT LEARNING OUTCOMES**

Empirical evidence and classroom-based observations indicate that students who engage with molecular modeling technologies achieve stronger learning outcomes compared to those taught exclusively through traditional methods. Such students demonstrate higher conceptual accuracy, particularly in topics involving stereochemistry, peptide bond formation, and protein structural levels.

The ability to explain complex processes such as protein folding, hydrogen bonding networks, and denaturation improves significantly when learners can visualize and manipulate structures dynamically. Modeling tools help students integrate symbolic formulas with three-dimensional representations, reducing misconceptions and strengthening representational competence. Furthermore, students develop stronger interdisciplinary connections between chemistry and biology. By exploring how molecular structure influences biological function, learners gain a more coherent understanding of biochemical systems. Increased confidence in explaining biomolecular mechanisms is also frequently observed, as visualization reduces cognitive uncertainty and enhances conceptual clarity.

**CHALLENGES AND LIMITATIONS**

Despite their clear educational benefits, molecular modeling technologies present certain practical and systemic challenges. One major limitation is the availability of technological infrastructure. Schools and institutions may lack sufficient digital devices, licensed software, or stable internet access necessary for advanced modeling platforms. Another significant factor is the need for teacher training. Effective implementation requires educators to possess both technological competence and methodological expertise in integrating modeling activities into lesson plans. Without adequate professional development, modeling tools may be underutilized or used superficially.

Time constraints within tightly structured curricula also pose difficulties. Modeling activities require exploration, discussion, and reflection, which may be challenging to accommodate within limited instructional hours. Additionally, unequal digital access among students can create disparities in learning opportunities. Therefore, successful implementation depends on institutional support, investment in infrastructure, and continuous professional development programs that empower teachers to apply modeling technologies effectively.

**ASSESSMENT STRATEGIES**

Assessment in modeling-based instruction should align with interactive and exploratory learning processes. Traditional memorization-based evaluation is insufficient for measuring structural understanding. Instead, assessment strategies may include model construction tasks in which students physically or digitally build amino acids and peptide structures. Digital modeling projects allow learners to demonstrate structural analysis and interpret molecular interactions. Conceptual explanation essays can assess students' ability to articulate structure–function relationships in their own words. Peer evaluation and collaborative presentations further support reflective learning and communication skills. Rubric-based performance assessment ensures transparency and consistency in evaluating modeling tasks. Importantly, formative assessment plays a central role throughout the learning process. Continuous feedback during modeling activities helps identify misconceptions early and supports incremental conceptual development.

**FUTURE DIRECTIONS**

The future of molecular modeling in chemistry education is closely connected to technological innovation. Emerging developments include AI-based molecular tutoring systems capable of providing personalized feedback and guiding students through complex structural analysis. Adaptive three-dimensional learning environments may adjust the level of complexity based on learner performance, enhancing individualized instruction. Integration with biotechnology modules could further connect molecular modeling to real-world applications in medicine, genetic engineering, and environmental science.

Cloud-based collaborative modeling platforms represent another promising direction, enabling students to co-construct and analyze molecular structures in shared digital environments. The incorporation of artificial intelligence into these systems has the potential to personalize learning experiences, diagnose misconceptions instantly, and offer adaptive guidance. In conclusion, molecular modeling technologies not only transform current instructional practices but also open new horizons for innovation in chemistry education, contributing to deeper conceptual understanding and the development of scientifically literate learners.

**CONCLUSION**

The integration of molecular model technologies into the teaching of amino acids and proteins significantly enhances conceptual understanding, spatial reasoning, and interdisciplinary competence. By transforming abstract molecular structures into interactive and visual experiences, these technologies bridge the gap between theory and visualization. Their application supports constructivist, inquiry-based, and STEAM-oriented pedagogical frameworks. Although technological and infrastructural challenges remain, the pedagogical benefits clearly outweigh the limitations. Molecular modeling technologies represent a powerful instructional innovation in modern chemistry education and

contribute to the development of scientifically literate and analytically competent learners.

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# PHILOLOGICAL SCIENCES

## MYTHOLOGICAL INTER-TEXTUAL MODEL IN POSTMODERN DISCOURSE BASED ON AZERBAIJAN LITERATURE

***Ibishli F.***
*PhD student,*
*Azerbaijan University of Languages*
*Faculty of Philology*
*Azerbaijani literature*
*https://orcid.org/0000-0002-7019-4045*
DOI: 10.5281/zenodo.19044572

**ABSTRACT**

The main study subject of the article is inter-textual postmodern text interaction with the legacy of Azerbaijan literature in modern period. A cultural dialogue being a semantic point of convergence of the text factual and ideological levels is in the focus of investigation. The purpose of the research undertaken is observation of the postmodern artistic unity transformational nature, represented by the projection of systemic/non-systemic writing//reading. Methodologically, the work is based on the receptive approach to identification of mythological features of the text and its semantic meanings. The analysis allowed us to direct attention to inter-textual variations in the newly created texts. The new era -modernist currents developed in Azerbaijan national literary since the 1990s. The article provides the answer to the questions based on various examples, the trends in a number of modernists (symbolism, impressionism, surrealism) and attempts to become a state of new time, the situation is bulging as a basic trendy.

The article is intended (field of application) for the Azerbaijan and foreign researchers of the postmodern discourse, intertextual communication, literary forms dialogue, signimic level text transformed into a semantic construct. The analysis results posit that formal inter-textual character in the text concept expands to the phenomenon, bearing convergent characteristics, and the semantic field extension can be carried out with the help of the receptive approach.

**Keywords:** postmodernism, reception of the text, discourse, dialogue, interpretation, inter-textual.

**Introduction**

Postmodernism is a movement in philosophy, art, and literature in the second half of the 20th century that denied all forms, rules, and dogmas, presenting them in a synthetic and mixed form. In the modern world, it has developed further as a result of the development of information technologies and has become the leading movement in the world.

Just as modernism once denied classical, academic values and created new artistic forms, postmodernism (German for "coming after modern") also denies modernism and creates chaos and diversity of elements in literature. According to the postmodernist American writer John Barth, postmodernism is an artistic experience that can be based on the culture of the past.

The theory of postmodernism was formed on the basis of the philosophical concept of the famous philosophers J. Lyotard, Jacques Derrida, and others. According to his philosophy, "the world is a text," "the text is the only possible model of reality." The philosopher-culturologist Michel Foucault and others played a major role in the preparation of the theoretical foundations of Poststructuralism, one of the sources of ideas underlying postmodernism. J. Barthes, T. Pynchon, C.P. Dunleavy, D. Bartel (representatives of the "school of black humor"), D. Delillo, J. Deleuze, F. Guattari, U. Eco, U. Gibson, C. Barnes, I. Calvino, etc. are considered prominent representatives of postmodernism.

The development of the Azerbaijani dramaturgy of the independence is the development of a classical drama and modern theater aesthetics. In recent years, the success of the national playground, Kamal Abdullah, Ali Amirlin, Ali Amirli, Hamid, Hamid, was represented by Hasanli Eyvazov's different works.

B.Vahabzade, M.Araz, I.Muganna, İ.Shikhli, Anar, Elchin, N. Hasanzadeh, S. Rustamkhanli, Z.Agubli, Z.Agub, K.Abdulla and others are created in a creative way, successfully benefited, all literary types and genres - poetry, prose, dramatic, novels, narratives and story examples. While metanarratives in postmodernist literature can realize the potential of the concept of "humanism", dual meanings, and ethnocultural values, postmodernism's focus on the non-existence of the subjective world, including the manipulation of the subjective world, is also a major challenge for postmodernist art. One of the main features of the novel, which is based on the idea of a historical novel, is the desire to use mythological texts, motifs, images and characters.

**Literature review**

Starting from the second half of the 20th century, modernism in leading countries went through a crisis and turned into postmodernism. Today, postmodernism is also showing itself in various fields of culture and philosophy.

In postmodernism, all boundaries are removed. Philosophy, culture, art, architecture and other concepts are mixed with each other. They are no longer separate trends, but they themselves are mixed together, turning into syncretism. In postmodernism, the essence of existence and things is not reached, everything is perceived without paying attention to its depths and sub-

tleties. The world is accepted as it is. If modernism replaced old views with new ones, in postmodernism the idea of the collapse of these innovations, of everything being simple, straightforward, clear and syncretic, is put forward [6].

If modernism replaced old concepts with new ones and gave rise to new trends, this goal is not pursued in postmodernism. Here, elitist concepts and the mass are identified, united, and put forward in game categories. Here, trends from systematic to chaotic, to confusion are felt. Long and difficult categories are given in the simplest concepts. Sciences, philosophy, arts and other fields belong not only to professionals, but to all people. The boundaries between them are erased, syncretic concepts arise. Here, as in modernism, traditions are not completely denied, but there may be a partial return to them. Pluralism, a departure from seriousness and an ironic view of the world, the absence of truth, the principles that writing does not reflect objective reality and creates a new reality, marginalism, the emergence of the Internet and other information spaces are among the features of postmodernism. Postmodernism is multifaceted, it resembles a "buffet". Whoever needs it, takes what he needs from there.

J. Derrida, one of the thinkers of postmodernism, considered it necessary to destroy (deconstruct) all traditional concepts. According to him, there are rules that are valued as truth. This is "logocentrism". Here everything is presented as a pair: literal-figurative, serious-banal, transcendent-empirical. Here the first is understood as the primary, the second as its special case. This order must be broken, the first concepts must be presented as a derivative of the second. For example, the metaphorical concept is not a special case of the literal meaning, but of the literal metaphor. Later, Derrida argued that writing is not important, not language and speech, which everyone attaches importance to. Because if there are symbols in language, their storage is in writing. Therefore, language and speech are a kind of incorrect writing, a derivative of it. Thus, Derrida calls into question all learned concepts. In his opinion, they are not at all true and fundamental, but only derivatives. The literary forms dialogue, texts cohesion, intertextual communication, "text-reader" opposition, "the world as a text" (Derrida) thesis, interactions field – these are the statements of the XX century literary theory where the dualistic correctness and semantic dispersion principle dominates. The game field of the reader is open to the maximum retrospection. Therefore, the reader's consciousness incorporates the whole literary-historical process, the sign level of the text being transformed into a semantic construct [10].

The transformational nature of postmodern artistic unity can be represented by the projection of systemic/non-systemic mechanism of writing/reading. This problem representation is promising both in terms of identifying the individual characteristics of the text, its functional characteristics, as well as by way of the idea of relative multiplicity of semantic correlates (Kiklewicz 2015), intertextual (Genette 1997; Graham 2000; Kiebuzinska 2001; Fatayeva 2007; and others) and discursive variations and speed imagery embodiment [14, 15].

*The main idea of intertextuality*

The study of intertextuality is important both in terms of theory (G. Genette, R. Barthes, J. Kristeva, J. Derrida, M. Riffaterre, M. Holquist, A. L. Nielsen, M. Pfister, A. Graham, N. Fairclough, M. Worton, S. Judith) and practice (N. Bratosevich, U. Broich, B. Johnson, C. G. Gonzalez, A. Haberer, A. Popovich). This multi--dimensional text category has direct access to the solution of literary criticism topical problems and holistic reception of the author's individual and personal style. "The theory of intertextuality destroys traditional notions of the origin of meaning, whether they are located in the sign (with a presumed stable signified) or the author (presumed God-like creator of meaning)". The fact that the categorical apparatus of this phenomenon has already been formulated, the basic forms and types of intertextual relations defined, and its markers exposed in the literary studies, does not diffuse the demand of intertextuality further study [14].

Intertextuality – is a basic text-creating and semantic category, assuming the process of dialogical interaction of texts in the planes of content and expression, carried out both at the level of the whole text and at the level of certain semantic and formal elements. According to narrow understanding intertextuality is limited by dialogical relationship in which one text contains explicit references to specific pre-texts. However, understanding of the given category cannot be reduced to mere citation, materialization of certain associative lines in the reader's consciousness, allusion formation and reminiscence.

The concept of intertextuality became common for the textological theory of postmodernism, admitting that interaction between the text and sign context serves as fundamental condition for sense creation. Deconstruction the principle of intertextual matrix makes it possible to objectify the plurality of semantic parallels. The meaning emerges as a result of linking semantic vectors, which draw in the broad cultural context acting as an external semiotic sphere for any text. Postmodernism synthesized the idea and theory of intertext. It is concerned with the artist's peculiar type of thinking, way text creation, unique artistic picture of the world formation. The concept of intertextuality is perceived by the theoretical autoreflection of postmodernism and at the same time by its normative poetics. It provides basis for estimating the postmodern style of thinking as thinking of citation, and for estimating postmodern texts as citatory literature built on the principle of intertextual matrix. For postmodernists, structure plays a major role but it is not a metaphysical absolute but a misty coupling of initial conditions yielding only indirect expression. It is a certain letter which is understood as a direct current statement and is perceived as a process of creation.

The intersection and mutual influence of postmodernism, a cultural phenomenon, with myth, folklore, and lore in various contexts is an undeniable fact of the contemporary world, as well as of the Azerbaijani literary process. Postmodern literature, which emphasizes the transformation of cultural forms, intertextual connections, and hybridity, makes intensive use of folklore, myth, and lore to create intra-textual allusions, parodies, deconstructions, symbols, and quotations. A writer who aims to create a postmodern text creates a

new text based on these materials in order to decanonize and deconstruct the themes of identity, history, and culture. The postmodern approach to folklore, myth, and lore leads to the manifestation of its classical motifs in a new context and form, to an emphasis on the hybridity of literary texts and contexts. Pertti J. Anttone's book "Tradition in Modernity: The Nation-State in Postmodernism and Folklore," which I'm currently reading, conceptualizes "tradition" and "folklore" within the discourses of modernity, modernism, and postmodernism. The central point of this study, which examines the manifestation of folklore in a contemporary format, in contemporary and postmodern realities, is the identification of the points of collision and demarcation between these two distinct cultural strata.

The central principle in this cultural context is the epistemological notion of the point of connection. The intersection and mutual influence of the two distinct cultural phenomena of postmodernism and folklore in various contexts is an undeniable fact of the contemporary world, including the Azerbaijani literary process. Postmodernist literature, emphasizing the transformation of cultural forms, intertextual connections, and hybridity, actively utilizes folklore to create intra-textual allusions, parodies, deconstructions, symbols, and quotations. A writer aiming to create a postmodernist text creates a new text based on folklore to decanonize and deconstruct themes of identity, history, and culture. The postmodernist approach to folklore results in the manifestation of its classified motifs in a new context and form, as well as an emphasis on the hybridity of literary texts and contexts.

**Conclusion**

In Azerbaijani postmodernism, folklore is also an important literary source and a fundamental poetic element. In our postmodernist literature, particularly in the works of Kamal Abdullah, Ilgar Fahmi, and Orhan Fikretoglu, folkloric motifs and images are synthesized with contemporary style and techniques, and used to create new works that blend traditional and contemporary literary heritage. Postmodernist examples of Azerbaijani literature demonstrate that the interaction and intersection of postmodernism and folklore in various literary and cultural contexts imbues our literature with new, complex, and multilayered works [1;3;6].

At first glance, the epic and postmodernism seem diametrically opposed. The epic, with its monumentality, heroic images, clear morality, and belief in objective truth, embodies archaic notions of a world frozen in time. Postmodernism, on the contrary, denies any absoluteness, ridicules pathos, and plays with fragments of the past. Postmodernism not only utilizes elements of the epic, but reinterprets, deconstructs, and parodies them. Postmodernism reinterprets the epic and creates it as a new text, applying the following principles:

*Deheroization (the loss of the hero's essential qualities):* Epic heroes typically possess superhuman qualities and perform feats for the sake of lofty ideals. Postmodernism often demeans heroes, sometimes turning them into antiheroes, exposing their weaknesses, shortcomings, and contradictions. Heroes of postmodern works can be indecisive, selfish, and even cowardly. Rejection of pathos: Epic poetry often uses pathos and solemnity to emphasize the importance of events and characters. Postmodernism ridicules pathos, replacing it with irony, satire, and the absurd [3].

*Questioning Truth*: Epics typically present themselves as objective truths, stories of what actually happened in the distant past. Postmodernism, on the other hand, questions the very existence of objective truth, demonstrating that history is always subjective and dependent on the narrator's perspective.

It's important to understand that the postmodern reinterpretation of the epic does not mean its destruction. It is an attempt to breathe new life into the epic, making it more relevant to the modern world. Postmodernism does not deny the value of the epic as a cultural heritage; it merely offers a new perspective on it, allowing us to look at it from a different angle. Thus, postmodernism doesn't simply play with elements of the epic, but uses them to create new, complex, and multifaceted works that reflect the contemporary state of the world. This allows us to take a fresh look at the past, understand its connection to the present, and reflect on the future. As a result, the encounter between the epic and postmodernism is not simply a clash of two eras, but a fruitful dialogue that enriches both literature and our understanding of the world. This dialogue can expect new, interesting, and unexpected interpretations of the epic in a postmodern environment. The future of literature will undoubtedly be marked by further interpretations of classical plots and forms, and the epic, as one of the oldest genres, will continue to inspire writers and poets to create new, captivating works [4].

Ilgar Fahmi's literary project "The Fox of Canlibel," distinguished by its postmodern character, is a deconstructed version of the epic "Koroğlu." This work can also be assessed as a professional "fan text"—a "fan fiction" written by the author on a specific epic. In this trilogy, Ilgar Fahmi masterfully navigates postmodern narrative through the myth-folklore-myth triangle, giving our contemporary prose a completely new work. Along with the ancient mythological and folkloric element of water, Ilgar Fahmi introduces a relatively “young” real-mystical image into the novel’s structure – the dervish, which he develops throughout the trilogy, revealing it in stages. Dervishes are presented in two types – in positive and negative contexts – in Azerbaijani literature. Dervishes with negative qualities, using magic and spells, turn people into stones, birds, and animals, enter into contact with evil forces, first giving children to the childless, and then attempting to steal them and destroy them. We encounter such dervishes in the tales “Three Sisters” and “Garagash.” Dervishes with positive qualities guide the lost, enter the hero's dreams and foretell their fate, help break spells and sorcery, and grant children to the barren. This type of positive dervishes is described in the fairy tale "The Condition of Barkhudar" and in Asar Tabrizi's work "Mehr ve Mushtaq." Isa Huseynov's novel "Makhshar" also mentions two types of dervishes: the Khurufi-Sufis and the black dervishes of Amir Temur. The former are dervishes of divine love and the path of truth, while the latter are spies and oppressors [4].

In N. Abdulrahmanli's novel "The Wayward One," the dervish we encounter serves as a symbol, explaining to a person lost in the maelstrom of life the true path and the essence of error. Dervishes are also described

in literary works as mediums, sorcerers, magicians, witches, and fortune tellers.

In Kamal Abdullah's "The Valley of the Magicians," dervishes also function as magicians. The dervishes-magicians in the work choose a place called the "Valley of the Magicians" as their refuge, retreat into seclusion, continue their existence in a special aura, time, and space, and, when necessary, intervene in real life. Dervishes in "The Valley of the Magicians" are also presented as seers, foreseeing the future. The roots of seers go back to the most ancient times of human society. Humanity, constantly living with the desire to know the future, to learn about what will happen, and to influence it, has discovered a number of divination methods to connect with the future, change something, and understand it: 1. Pyromancy (using fire); 2. Morphoscopy or physiognomy (using the structure of the human body); 3. Arithmomancy by numbers); 4. Geomancy [by the vibration of the earth]; 5. Ophiomancy [by snakes]; 6. Critomancy [by insects]; 7. Ornithomancy [by birds]; 8. Catanstromancy [by mirrors]; 9. Oneiroscopy [by dreams]; 10. Presmology [by revelation]; 11. Necromancy [by spirits]; 12. Kohinomancy (using sieves) [3-6].

Dervish figures described in Azerbaijani literature employ several of these methods. In Azerbaijani fairy tales and epics, dervishes primarily employ pyromancy, performing divination using a brazier filled with coals. In "Kitabi-Dede Gorgud" and other epics, we find traces of oneiroscopy, for example, in the "black dream" of the Kazan Khan. Dede Gorgud's predictions may be an example of presmology. M. Seyidov associates his predictions with fire and notes that, in general, fire and the sun are means of seeing the future. In K. Abdullah's work "The Valley of the Wizards," a wandering sorcerer uses necromancy.

Although the Koroglu epic is deconstructed in Ilgar Fahmi's trilogy "The Fox of Canlibel" at the level of plot, character, and language, the epic's core idea (patriotism), the heroes' characteristics (heroism, loyalty, purity), and the setting (Canlibel) are preserved. Thus, the trilogy does not negate the national-cultural text, but merely offers a new deconstructive variation.

**Limitation**: the study has potential limitation related to access information. Lack of prior research studies on this topic was the main challenge during the investigation.

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# TECHNICAL SCIENCES

## SHARED MEMORY STATE MANAGEMENT IN MULTI-WORKER PHP WEBSOCKET SERVERS: A CASE STUDY WITH OPENSWOOLE AND SWOOLE\TABLE

***Seyidova I.***
*Azerbaijan State Oil and Industry University, associate prof.*
***Shamusuinov R.***
*Azerbaijan State Oil and Industry University, Master's student*
*Baku, Azerbaijan*
DOI: 10.5281/zenodo.19044586

**ABSTRACT**

The research investigates how PHP WebSocket servers with multiple workers share their memory state through shared memory. Persistent WebSocket servers in multi-worker PHP environments experience a state-sharing issue which does not affect regular PHP usage because worker processes use separate memory areas and normal PHP structures cannot connect those memory areas. The research work evaluates the issue based on the OCPP 1.6 electric vehicle charging management system we created and deployed on OpenSwoole. On the initial testing we tracked the failure modes when per-process PHP arrays began to differ between workers. It made us perform transformation from PHP arrays to Swoole\Table for shared memory purposes as well as designed a bidirectional lookup table which enabled command routing between different workers. Swoole\Table provided us an efficient solution to track connections with sufficient capacity for our operational needs.

**Keywords**: OpenSwoole, Swoole\Table, WebSocket, shared memory, multi-worker, PHP, OCPP, cross-worker communication.

### 1.Introduction

Swoole and its OpenSwoole fork made PHP competitive with Node.js and Python and Java which already includes persistent TCP servers and WebSocket endpoints and long-running daemons [1, 5, 6, pp. 80-83]. The model shows a sharp break from the established PHP development practices. The traditional PHP system creates a new process for each request and sends back the response after which it terminates its entire processing pipeline. OpenSwoole operates through a system maintaining permanent workers within a central event loop. The OCPP (Open Charge Point Protocol) requires continuous two-way communication between a central server and a fleet of EV chargers [2, 7].

On initial implementation running one worker was fine during development with two test chargers. We decided to expand the number of workers because a single PHP process cannot handle hundred of simultaneous WebSocket connections without blocking. More workers means the server distributes the load and stays responsive even when one handler runs slow database query. It created a different problem we had not planned for. Each worker gets its own copy of every PHP variable. Our connection tracking array which worked perfectly in a single process now existed as four independent copies. Worker zero has registered a charger and worker two has absolutely no record of it. A write in one worker was invisible everywhere else.

The research work describes our operational experience with a connection state management system which we built for the OCPP 1.6 central management system on OpenSwoole.

The main contributions of this work are as follows:

- The development process revealed failure modes which resulted from isolating per-process arrays which worked properly during development but failed in production.
- The Swoole\Table design provides a bi-directional connection lookup system which separates the inbound lookup path from the outbound lookup path.

### 2.Background

2.1 OpenSwoole Process Architecture. OpenSwoole works as a PHP C-extension that replaces the typical request-response cycle with a persistent event-driven server model. The master process creates multiple worker processes according to the number of workers which the system administrator has determined. Each worker receives a complete PHP environment with its dedicated memory and variable space and database access. The master system controls network input through its reactor threads while dedicated internal communication systems distribute incoming data to worker units [1].

The existing system offers PHP developers unexpected protection features which operate throughout the system. The master process restarts a worker which crashed due to an unhandled exception within milliseconds. All other workers remain operational and their connections stay unaltered. The system uses process isolation to create protection against faults, on the other hand this isolates processes in different workers.

We run four workers:

```
$this->server = new Server($host, $port);
$this->server->set([
   'worker_num' => 4,
   'task_worker_num' => 4,
   'heartbeat_check_interval' => 30,
   'heartbeat_idle_time' => 60,
]);
```

OpenSwoole will terminate any connection which remains inactive for 60 seconds according to the heartbeat parameters. Without a FIN packet, the server only identifies a lost charger when 60 seconds pass without any activity. We set that threshold to match the OCPP heartbeat interval. Missing a single heartbeat cycle

closes the connection, which forces the charger to reconnect after it recovers.

2.2 WebSocket File Descriptors and Worker Affinity. OpenSwoole assigns an integer file descriptor number (fd) to each ongoing WebSocket connection [4]. This is a detail the documentation does not make obvious. fds are bound to the worker that accepted them. The worker who owns $server->push($fd, $data) is the only one who can use this command. The other workers cannot use the command because it will produce no visible output. The system does not produce exceptions or errors, yet the information never reaches its destination. We spent a significant amount of time investigating command delivery errors until we grasped this requirement, which serves as the foundation for everything explained in Section 4.

2.3 Swoole\Table. The Swoole\Table component provides workers with a C-based in-memory hash table which they can access and modify without requiring lock mechanisms or designated inter-process communication methods [3]. The API is intentionally constrained: developers must define column names and types before the server begins operation, and the system enforces row limits from the moment of initial setup. The system defines three column types which include TYPE_INT for 64-bit signed integers TYPE_FLOAT for double precision numbers and TYPE_STRING for fixed-length byte arrays. There is no other content. The table resides in a shared memory region allocated via mmap, which all worker processes map into their own address space. All processes access the same physical memory through their mapping system. Row-level spinlocks manage multiple processes which need to access the same data so developers do not need to implement any additional synchronization mechanisms. The system operates with high speed and basic functionality, though its architectural constraints, however require careful consideration during design.

**3. The Problem: PHP Arrays in a Multi-Worker Context**

3.1 The Naive Implementation. The problem involves multiple workers who need to use PHP arrays. Our initial connection tracking system analysis revealed serious weaknesses in its basic design. A plain PHP associative array, declared as an instance property:

```
// First version — before Swoole\Table migration
protected array $connections = [];
```

The system established connections using charger metadata which went in keyed by fd:

```
$this->connections[(string)$fd] = [
   'idTag' => $idTag,
   'charger_id' => $charger->id,
   'connected_at' => time(),
];
```

The development process operated without problems. The system functioned perfectly with a single worker accessing a single array, however it experienced two different types of failure that emerged after we moved to operational mode with four workers.

3.2 Cross-Worker Lookup Failure. The HTTP layer experienced intermittent problems which resulted in "connection not found" errors when it attempted to command a charger. The situation unfolded with the charger first establishing its connection. OpenSwoole hands the event to worker #0. Worker #0 stores the metadata in its local $this->connections. The user opens the mobile application and begins charging their device. The mobile demand resulted in an HTTP request which worker #2 received. Worker #2 serves to retrieve the charger information. Its $this->connections is empty. It has no idea worker #0 registered anything. The command resulted in an error which the user experienced as a system failure. The same worker needs to handle both connection and command operations for correct system operation. It led to a 75% failure rate for any charger-command pair when operating with four workers and using round-robin dispatch.

3.3 Worker Recycling. The second failure was sneakier. The OpenSwoole system implements periodic worker recycling to control memory usage throughout its extended operating periods. A recycled worker's replacement starts fresh: all instance properties reset to their defaults. The connections array? Disappeared.

The tracking table lost all chargers who had their connections authorized by the previous worker. The existing file descriptors maintained their operational status while chargers continued to send heartbeats but the system lost all record of their ongoing connections. The operators observed chargers disappearing from the system dashboard which then became unresponsive to command requests until they reconnected during their next connection cycle. The system operated without any log entry or error message to reveal the actual cause of the problem. The process of linking the observed symptom to its actual root cause required us additional time than we had predicted.

**4. Solution: Swoole\Table for Cross-Worker State**

4.1 Table Design. We implemented Swoole\Table for monitoring operational links between its system elements. The Table Design process needed to conduct Swoole\Table migration as its first task to identify the correct lookup operation to perform.

OCPP messages enter the system through inbound signals that include a file descriptor. The server needs to determine which charger sent the messages. The application layer requires the identification of the charger together with its idTag value to establish a connection through the fd link.

A single table can execute one function only when it performs a complete row scan. The situation required us to develop two distinct tables.

We implemented forward mapping to track connections through fd links:

```
$this->connections = new \Swoole\Table(2048);
$this->connections->column('connected_at', \Swoole\Table::TYPE_INT);
$this->connections->column('idTag', \Swoole\Table::TYPE_STRING, 64);
$this->connections->column('charger_id', \Swoole\Table::TYPE_INT);
$this->connections->column('charger_name', \Swoole\Table::TYPE_STRING, 128);
$this->connections->column('ip', \Swoole\Table::TYPE_STRING, 64);
$this->connections->create();
```

And reverse mapping to create fdCache which tracks connections through idTag:

```
$this->fdCache = new \Swoole\Table(2048);
$this->fdCache->column('fd', \Swoole\Table::TYPE_INT);
$this->fdCache->column('worker_id', \Swoole\Table::TYPE_INT);
$this->fdCache->column('updated_at', \Swoole\Table::TYPE_INT);
$this->fdCache->create();
```

Both tables must be created before $server->start(). If tables were created inside a worker, each worker would allocate its own separate copy in its own memory — defeating the entire purpose. Creating them first in the constructor ensures all workers share the same mmap region owned by the master process.

The worker_id column exists in fdCache because it can only perform pushes through the worker who owns it. The outbound routing logic needs this column to decide whether it can push directly or requires another worker to handle the task.

Swoole\Table pre-allocates everything upfront. The system fails to insert new items without showing any error messages when the limit is reached. The system creates permanent memory waste by setting it to excessive levels. The storage limit of 2048 was selected because it exceeds our present fleet capacity while providing room for future expansion. The system will redirect its binding constraint to other bottlenecks which stem from network restrictions and database throughput limitations once the system reaches its maximum capacity.

4.2 Connection Lifecycle. The system inserts into both tables when a charger gets connected on the onOpen process:

```
$this->connections->set((string)$fd, [
    'connected_at' => time(),
    'idTag' => $idTag,
    'charger_id' => $charger->id,
    'charger_name' => $charger->name ?? '',
    'ip' => $request->server['remote_addr'] ?? '',
]);

$this->fdCache->set($idTag, [
    'fd' => $fd,
    'worker_id' => $server->getWorkerId(),
    'updated_at' => time(),
]);
```

In shared memory system all workers receive instant access to these writes. The inbound messages use onMessage to search for $fd within the connections to locate the corresponding charger. The outbound commands extract the fd and worker details from fdCache after conducting an idTag search.

**5. Cross-Worker Command Routing**

5.1 The Routing Problem. When an operator triggers a command from the dashboard, it arrives at the Swoole server as an internal HTTP request. Any worker can receive it. The master process is a C-level network handler with no PHP runtime. It does not route pushes. The worker that gets the request has the charger's idTag but almost certainly does not own its WebSocket fd. Push from the wrong worker returns false silently. No exception, no log entry. We spent time chasing what looked like dropped commands before we understood this.

5.2 Inter-Process Pipe Routing. OpenSwoole gives workers a way to talk to each other: $server->sendMessage($data, $workerId) sends a payload through a Unix pipe to a target worker, which receives it in onPipeMessage. We use this to hand off push operations to the fd owner.

The logic is straightforward. Look up fdCache, compare worker IDs, push directly in case of match or route:

```
$cached = $this->fdCache->get($idTag);
$targetWorkerId = $cached['worker_id'];
$currentWorkerId = $server->getWorkerId();

if ($targetWorkerId === $currentWorkerId) {
    // Same worker: direct push
    $server->push($cached['fd'], $command);
} else {
    // Different worker: route via pipe
    $server->sendMessage([
        'action' => 'ocpp_command',
        'ocpp_fd' => $cached['fd'],
        'command' => $command,
        'idTag' => $idTag,
        'type' => $commandType,
    ], $targetWorkerId);
}
```

The receiving worker executes the push operation:

```
if ($action === 'ocpp_command') {
    $ocppFd = $message['ocpp_fd'] ?? null;
    $command = $message['command'] ?? null;

    if ($ocppFd && $command && $server->isEstablished($ocppFd)) {
        $server->push($ocppFd, $command);
    }
}
```

The same pipe handles dashboard status updates. A charger's StatusNotification arrives at one worker but the browser watching that charger may be connected through another. Same lookup, same pipe.

**6.Discussion**

6.1 Performance Characteristics. The Swoole\Table implementation performs hash-based lookups directly in shared memory which provides stable and predictable execution times. The Heartbeat handler typically finishes its work within a time frame of 50 milliseconds in the tested configuration. The program requires minimal resources because it needs only one database update and one table lookup to complete its tasks. The MeterValues handlers need to access the shared table multiple times while they perform several Eloquent queries. The actual execution time for these tasks ranges from 50 to 100 milliseconds because it depends on how heavy the workload becomes. Database interactions make up more than 95 percent of the total time handlers require to complete their tasks according to profiling data. The shared memory layer does not create any noticeable performance issues which means its performance stays constant under standard operational conditions. The system design demonstrates that database access functions as the main system limitation which prevents inter-process memory operations from affecting system performance. The fleet system works

properly when four worker processes handle typical operational demands. The system can handle sudden traffic surges or unplanned operational increases by activating extra worker capacity. Message processing efficiency improves with worker count. Each worker uses its own database driver instance to handle messages. The system has some extra capacity but adding more workers will not create any advantages. The costs to operate them exceed the profits they will produce.

6.2 Limitations of Swoole\Table. Swoole\Table is fast but it imposes several architectural constraints that designers need to account for. First, the schema is fixed at initialization. The server requires all column definitions to complete before it can start operation which prevents any structural changes from happening until a restart occurs. It allows users to save certain flags and extra fields like the Restart indicator in Redis or a relational database for temporary upgrades but table definitions remain unchanged since they need to be available all the time. The deployment process gets complicated because there are rules which prevent system upgrades to work between different system versions. Second table capacity must also be specified at startup. The examined system configuration restricted the table database to a total of 2048 rows. The system needs a full restart with new settings to handle situations when users try to access data beyond their permitted limits. The set method fails to deliver clear information about capacity restrictions during its operation. The system functions normally based on return values but it stops adding new records after reaching its maximum capacity. Swoole\Table depends on memory mapping to keep all its data available in shared process memory. The master process needs to stay active because any master termination results in permanent data deletion. The system manages this danger through its automatic charger reconnection feature which restores lost table data during the next heartbeat period. The table permits users to perform key-based access but lacks any built-in query abstraction features. It performs O(1) lookups when they enter the specific key fd or idTag. Users must complete full table scans to conduct operations like range queries filtering or aggregation. The design enables fast point lookups but it lacks support for analytical or reporting tasks.

6.3 Comparison with Alternative Approaches. Redis was evaluated as a potential alternative architecture. Redis provides users with optional data persistence and dynamic data structures and pub/sub functionality together with its ability to expand storage space. The system works better when deployed across larger fleets or distributed systems. Redis creates network delays because it requires multiple service connections to send and receive data between different services. Swoole\Table runs entirely within shared memory on a single host, so there is no network round-trip at all. Redis adds a network hop for every read and write, which matters at high message frequency. The trade-off between distributed flexibility and local performance efficiency creates system structure problems. The current host will reach its resource limits which forces the system to shift into a distributed solution. The machine-based routing system shown in Section 5 cannot function outside its designated machines.

**7.Conclusion**

The architecture based on shared memory which was utilized to build a PHP WebSocket server that supported multiple workers operated in production for more than one year. The Swoole\Table technology enables workers to share state information reliably through O(1) data lookup which requires no additional external resources. The system design needs fixed design requirements because it relies on permanent schema design and permanent capacity design which restricts data access to essential element key lookup.

The bidirectional table design — fd-keyed forward mapping, idTag-keyed reverse mapping with worker affinity - is reusable. Any WebSocket server that requires both inbound identity resolution and outbound command routing will develop a solution which resembles our existing system. Future work includes migrating to OCPP 2.0.1 and evaluating coroutine-based database drivers to eliminate the blocking calls that currently dominate handler latency.

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Editorial office: Křižíkova 384/101 Karlín, 186 00 Praha

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